

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXX.

February 11, 1870.

No. 4.

Professor J. C. ADAMS, Vice-President, in the Chair.

W. A. Harris, Esq., Balliol College, Oxford,
was balloted for and duly elected a Fellow of the Society.

Report of the Council to the Fiftieth General Meeting of the Society.

Progress and present state of the Society:—

	Compounders.	Annual Contributors.	Non-residents.	Patroness, and Honorary.	Total Fellows.	Associates.	Grand Total.
December 31, 1868	182	296	12	3	493	45	538
Since elected ...	6	29	...	...	...	...	...
Deceased	—4	—5	—1	..	...	...	...
Removals	+3	—3	...	...	...	...	...
Resigned	...	—6	...	...	...	...	...
Dec. 31, 1869 ...	187	311	11	3	512	45	557

*Report of the Council**Mr. Whitbread's Account as Treasurer of the R*

RECEIPTS.

			£	s.	d.	£	s.
Balance of last year's account	...	...	390	14	3		
Error in the Petty Cash Account	...	...	0	0	4		
						390	14
By Dividend on £3000 Consols	...	...	43	17	6		
By ditto on £5000 New 3 per Cents	...	...	73	2	6		
By ditto on £3200 Consols	...	...	47	0	0		
By ditto on £5000 New 3 per Cents	...	...	73	8	9		
						237	8
On account of arrears of contributions	...	...	135	4	0		
155 annual contributions	...	...	325	10	0		
32 admission-fees	...	...	67	4	0		
28 first years' contributions	...	...	42	0	0		
						569	18
10 compositions	...	...	...	...	...	210	0
Sale of publications:—							
At the Rooms of the Society	...	...	10	2	6		
By Messrs. Williams and Norgate, Publishers	...	...	23	16	8		
						33	19

£1442 0

onomical Society, from January 1 to December 31, 1869.

EXPENDITURE.

Salaries:—	£	s.	d.	£	s.	d.
Editor of Publications	60	0	0			
Assistant Secretary	130	0	0			
" " Gratuity	20	0	0			
Commission on Collecting	29	0	0	239	0	0
Taxes:—						
Land and Assessed	3	5	6			
Income	2	10	0			
Poor Rate	3	10	10			
Other Parish Rates	3	2	6	12	8	10
Bills:—						
Strangeways and Walden, printers ...	282	9	8			
Rumfitt, bookbinder	12	19	7			
Basire, engraver	54	10	0			
Pound, " 	117	12	0			
Malby and Son, lithographers	98	2	1			
Cundall and Co., photographers	3	8	0			
Insurance	7	15	6	576	16	10
Miscellaneous items:—						
House expenses	23	1	9			
Postages	43	16	11			
Books and parcels	3	7	9			
Expenses of evening meetings	13	13	0			
Waiters attending meetings	3	17	0			
Coals and wood	12	0	0			
Gas	6	13	7			
Repairs	2	8	6			
Sundries	12	1	4	120	19	10
				949	5	6
Lee Fund	6	0	0			
Turnor Fund	1	6	0			
Mrs. Jackson Gwilt's annuity, 1 year ...	8	15	0	16	1	0
Investment:—						
Purchase of £200 Consols	186	0	0			
" " " 	187	15	0	373	15	0
Banker, Noting Bill				0	1	6
				1339	3	0
Balance at Banker's				102	17	6
				£1442	0	6

ROBT. J. MANN, M.D. }
 C. G. PRIDEAUX, } *Auditors.*
 F. C. PENROSE, }

Assets and Present Property of the Society, January 1, 1870:—

					£	s.	d.	£	s.	d.
Balance at Banker's	...	...	...	...	...	...	...	102	17	6
1 Contribution of 8 years' standing	...			...	16	16	0			
8 " 6 " ...	...			...	100	16	0			
13 " 5 " ...	...			...	136	10	0			
4 " 4 " ...	...			...	33	12	0			
19 " 3 " ...	...			...	119	14	0			
20 " 2 " ...	...			...	84	0	0			
40 " 1 " ...	...			...	84	0	0			
Balance of an Account...	...	...	...	...	2	12	0			
2 admission-fees, and subscriptions	...			...	13	13	0			
								591	13	0
Due for Publications	...	...	...	...	...	...	...	2	14	0
£5000 New 3 Per Cents (including Mrs. Jackson's Gift, £300).										
£3400 Consols, including the Lee Fund (£100) and Turnor Fund (£500).										
Unsold Publications of the Society.										
Various astronomical instruments, books, prints, &c.										
Balance of Turnor Fund (included in Treasurer's Account)								139	12	0

Stock of volumes of the *Memoirs*:—

Vol.	Total.	Vol.	Total.	Vol.	Total.
I. Part 1	13	XII.	192	XXV.	199
I. Part 2	53	XIII.	202	XXVI.	204
II. Part 1	71	XIV.	394	XXVII.	459
II. Part 2	35	XV.	176	XXVIII.	419
III. Part 1	87	XVI.	202	XXIX.	451
III. Part 2	106	XVII.	185	XXX.	200
IV. Part 1	105	XVIII.	180	XXXI.	176
IV. Part 2	116	XIX.	187	XXXII.	207
V.	128	XX.	183	XXXIII.	212
VI.	154	XXI. Part 1	216	XXXIV.	200
VII.	178	XXI. Part 2	100	XXXV.	179
VIII.	164	XXI. (together).	94	XXXVI.	263
IX.	167	XXII.	185	(with M. N.)	
X.	177	XXIII.	180	XXXVI.	56
XI.	187	XXIV.	187	(without)	
				XXXVII.	795
				Part 1	

The instruments belonging to the Society are as follows:—

The *Harrison* clock,
 The *Owen* portable circle,
 The *Beaufoy* circle,
 The *Beaufoy* transit,
 The *Herschelian* 7-foot telescope,
 The *Greig* universal instrument,
 The *Smeaton* equatoreal,
 The *Cavendish* apparatus,
 The 7-foot Gregorian telescope (late Mr. Shearman's),
 The Variation transit (late Mr. Shearman's),
 The Universal quadrant by Abraham Sharp,
 The *Fuller* theodolite,
 The Standard scale,
 The *Beaufoy* clock, No. 1,
 The *Beaufoy* clock, No. 2,
 The *Wollaston* telescope,
 The *Lee* circle,
 The *Sharpe* reflecting circle,
 The *Brisbane* circle,
 The *Baker* universal equatoreal.

The *Sheepshanks'* collection of instruments, viz.,—

1. 30-inch transit, by Simms, with level and two iron stands.
2. 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
3. $4\frac{6}{10}$ -inch achromatic telescope, about 5 feet 6 inches focal length; finder, rack motion; double-image micrometer; object-glass micrometer; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters, with equatorial stand and clock movement.
4. $3\frac{1}{4}$ -inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
5. $2\frac{3}{4}$ -inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
6. $2\frac{3}{4}$ -inch achromatic telescope, about 30 inches focus; one terrestrial and four astronomical eyepieces.
7. 2-foot navy telescope.
8. 45-inch transit instrument, with iron stand, and also Y's for fixing to stone piers; two axis levels.
9. Repeating theodolite, by Ertel, with folding tripod stand.
10. 8-inch pillar-sextant, divided on platinum, with counterpoise stand and horizon roof.
11. Portable zenith instrument, with detached micrometer and eyepiece.
12. 18-inch Borda's repeating circle, by Troughton.

13. 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms.

14. A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, with extra pair of parallel plates; tripod staff; in which the telescope tube is packed; repeating table; level collimator, with micrometer eyepiece; and Troughton's levelling staff.

15. Level collimator, plain diaphragm.

16. 10-inch reflecting circle, by Troughton, with counterpoise stand; artificial horizon, with metallic roof; two tripod stands, one with table for artificial horizon.

17. Hassler's reflecting circle, by Troughton, with counterpoise stand.

18. 6-inch reflecting circle, by Troughton, with two counterpoise stands, one with artificial horizon.

19. 5-inch reflecting circle, by Lenoir.

20. Reflecting circle, by Jecker, of Paris.

21. Box sextant and 3-inch plane artificial horizon.

22. Prismatic compass.

23. Mountain barometer.

24. Prismatic compass.

25. 5-inch compass.

26. Dipping needle.

27. Intensity needle.

28. Ditto ditto.

29. Box of magnetic apparatus.

30. Hassler's reflecting circle, with artificial horizon roof.

31. Box sextant and $2\frac{1}{4}$ -inch glass plane artificial horizon.

32. Plane speculum artificial horizon and stand.

33. $2\frac{1}{2}$ -inch circular level horizon, by Dollond.

34. Artificial horizon roof and trough.

35. Set of drawing instruments, consisting of 6-inch circular protractor; common ditto; 2-foot plotting scale; two beam compasses and small T square.

36. A pentagraph.

37. A noddly.

38. A small Galilean telescope, with the object lens of rock-crystal.

39. Six levels, various.

40. 18-inch celestial globe.

41. Varley stand for telescope.

42. Thermometer.

43. Telescope, with the object-glass of rock crystal.

These are now in the apartments of the Society, with the exception of the following, which are lent, during the pleasure of the Council, to the several parties under mentioned, viz.:—

The *Fuller* theodolite, to the Director of the Sydney Observatory.

The *Beaufoy* transit, to the Observatory, Kingston, Canada.

The *Sheepshanks* instrument, No. 1, to Mr. Lassell.

Ditto ditto No. 2, to Mr. Huggins.

Ditto ditto No. 4, to Rev. C. Lowndes.

Ditto ditto No. 5, to Mr. Birt.

Ditto ditto No. 6, to Rev. J. Cape.

Ditto ditto No. 8, to Rev. C. Pritchard.

Ditto ditto No. 9, to the Director of the
Sydney Observatory.

Ditto ditto No. 41, to Rev. C. Pritchard.

Ditto ditto No. 43, to Mr. Huggins.

The 6-inch circular protractor, to Mr. Birt.

The Gold Medal.

The Council have awarded the Gold Medal to M. Delaunay for his *Théorie de la Lune*.

Professor Adams will, in the unavoidable absence of the President, through ill health, explain the grounds of this award.

Printed Transactions of the Society.

Part I. of Volume XXXVII. of the *Memoirs* has been published since the last Report. This Part contains the observations of Col. Tennant on the Solar Eclipse of August 1868. The Part is illustrated by ten plates.

The papers printed in the *Memoirs* of the Society form but a small part of the contributions to the science of Astronomy which have been given to the world through our Society. In the *Monthly Notices*, already in the hands of the Fellows, will be found many papers of interest. In addition to those which form the subject of separate paragraphs of this Report may be mentioned here:—

The Society is indebted for Papers by Prof. Cayley on the attraction of Ellipsoids; on Lambert's theorem of Elliptic motion; and on the determination of a Planet's orbit from three observations.

Mr. Mann's observations of the transit of *Mercury*, Nov. 1868, and Sir T. Maclear's micrometric measures of that planet, which make its observed diameter less than the tabular diameter by 1".50. Mr. Proctor has contributed numerous papers to our *Notices*; amongst which, one found in the March Number, on the Transit of *Venus*, 1874, will be especially referred to in another place.

Mr. Balfour Stewart read a short paper suggesting that many auroral appearances, and possibly the zodiacal light, might be caused by convection currents in the upper regions of the Earth's atmosphere, which, being conducted and moving under the lines of the Earth's magnetic force, might be supposed to be vehicles of electric currents.

Mr. Browning, besides observational papers, has described a new form of spectroscope for the telescope, and a method of using an illuminated cross for the measurement of lines in spectra.

OBITUARY.

The Society has to regret the loss by death of the following Fellows:—

A. K. Barclay, Esq., F.R.S.
 Capt. Blake, F.R.S.
 Eddowes Bowman, Esq.
 E. W. Brayley, Esq., F.R.S.
 J. Dickinson, Esq., F.R.S.
 Prof. Donkin, F.R.S.
 Chas. Mason, Esq.
 Benj. Naylor, Esq.
 Dr. P. M. Roget, F.R.S.
 John Smith, Esq.
 Sig. J. Vertu.
 Rev. C. Walters.

WILLIAM FISHBURN DONKIN was the eldest surviving son of parents remarkable for talent and excellence of character. He was born at Bishop Burton, in the county of York, on the 15th of February, 1814. Very early in life his taste for languages, mathematics, and music, became apparent, and, in addition, he possessed such perseverance and love of acquiring knowledge, that almost before he left the nursery he was known to cry when help was forced upon him which he felt he did not need, and which deprived him of the discovery he wanted to make for himself. The education he received from his father also developed a love for physics and chemistry. In 1829 his family moved to York, in order that he might have the advantage of attending a public school without losing the benefit of home influences. Here, at St. Peter's School, and under the care of Mr., afterwards Archdeacon, Creyke, he made rapid progress in classical learning. To the years spent at this school and directed in his studies by that able master, whom, as a teacher he considered perfect, William always looked back with special pleasure and gratitude.

In October 1832 he matriculated at St. Edmund's Hall, Oxford, and began to reside in the following term. On the installation of the Duke of Wellington as Chancellor of the University he recited the Greek ode. In 1834 he obtained a classical

scholarship at University College; in 1836 a first class in both classics and mathematics; and, in the following year, the Mathematical and Johnson mathematical scholarships, both of which were open to the University.

Soon after this he was elected Fellow of his own College, where he remained for the next six years, holding the post of Mathematical Lecturer, and other College offices. During these years he became known by various publications, among which may be mentioned an "Essay on the Theory of the Combination of Observations," written for the Ashmolean Society, and a very able article on Greek Music published in Dr. Smith's *Dictionary of Antiquities*.

In 1842 he was advised to stand for the Professorship of Astronomy, then vacant by the resignation of Mr. Johnson, since then Dean of Wells; and this he obtained, being at that time 28 years of age. Soon afterwards he became Fellow of the Royal Society, and also of the Royal Astronomical Society. In 1844 he married the third daughter of the Rev. John Hawtrey, at that time Incumbent of St. James's Church, Guernsey.

But even then he was beginning to suffer from a delicacy of constitution, which became a cause of great anxiety to his family; and in the midst of the most hopeful anticipations for science, when his rare abilities seemed to promise some of the discoveries which only fall to the lot of such men as he,—even then he was obliged from time to time to relinquish the duties and occupations in which he delighted, in order to try and preserve in other climates the health which was gradually leaving him. In the intervals of improvement he continued with untiring energy to attend to the duties of his Professorship, and to the advance of science in its various branches in Oxford; and during the years extending from 1850 to 1860 he sent to the Royal Society a few important papers, among which may be named one "On the Equation of Laplace's Functions," and a longer one "On a Class of Differential Equations, including those which occur in Dynamical Problems." Beyond this there is little to say of those long years during which a life that might have been one of the highest distinction was kept in check by illness and consequent inability to work. Those who knew him best, know how brightly the intellect, which otherwise might have enlightened the world, shone in the narrower sphere to which it was now confined; how his failing strength seemed only to enhance the energy that never stopped short of the limits which his state of health set to its achievements, because unable to pass beyond them; the patience that never once complained through all the weariness and comparative obscurity of his life; and the cheerfulness of character and brilliant cleverness which made a centre of happiness to his home and to his friends.

His last work, undertaken towards the close of 1866, was to prepare a book on Acoustics for the Clarendon Press series. For this he was singularly fitted, his acquaintance with practical and

theoretical music being scarcely less extensive and accurate than his knowledge of mathematics; but his increasing illness delayed the work, and the first part was still passing through the press when his friends became aware that he was about to leave them.

His death, on the 15th of November, 1869, cast a shadow over the University of Oxford, which mourned in him one who exhibited that rare combination of the highest scientific powers with the faith of a humble and sincere Christian.

The Rev. C. WALTERS came of a Welsh family, which settled first in the county of Dorset, but, about 200 years since, in Hampshire. His father, the eldest of three sons, was sent to Winchester College, under Dr. Warton (whose good opinion he won and kept), where he left a good name behind him, and made friendships which he maintained, more or less, in after life, with some who subsequently rose to rank and distinction in the University and the Church. His son, the subject of this memoir, was his only child, and he seems to have imbibed, in very early life, a taste for scientific and literary pursuits, his attention having been especially directed towards the former by his uncle, the Rev. John Vodin Walters, whom he ever regarded as a second father, and in whose memory he delighted to the last. He graduated at Oxford about the year 1808, after the usual residence at St. Mary Magdalene Hall. After his ordination he became Curate of Soberton, afterwards of Corhampton and Bishop's Waltham, then Rector of Bramdean, which he resigned for the Rectory of Wyke, near Winchester.

In regard to literary and scientific subjects, the old fire in him never ceased to burn; he gave frequent lectures at scientific institutions, and for many years was President of the Winchester Mechanics' Institute. He was elected a Fellow of this Society in 1838. He died at the advanced age of 85 years, and was buried in Winchester Cemetery.

JOHN DICKINSON, Esq., F.R.S., who died at his residence in Upper Brook Street, on the 11th January, 1869, had nearly completed his 87th year. He had for many years been engaged in the manufacture of paper, many important improvements in which were due to him. His energies were not, however, confined to manufacturing and mechanical details. He took a lively interest in all scientific pursuits, and during his lengthened life was intimate with many distinguished authors and men of science, by whom his varied information, sound sense, and conversational powers, were much appreciated. Besides being a Fellow of this Society he was a member of other learned bodies; in 1845 he was elected a Fellow of the Royal Society, to which he communicated a paper on the supply of water from the chalk stratum in the neighbourhood of London, which contains valuable information as to the amount of the rainfall in Hertfordshire, and the proportion of it which finds its way by percolation to supply the

springs in the chalk. In his latter years he took great interest in astronomy, and erected an observatory at his country house, Abbott's Hill, near Hemel Hempstead. In his astronomical pursuits he was much encouraged by his friendship with the late Admiral Smyth; but though his observatory was furnished with a fine equatoreal and a transit instrument, his advanced age prevented his making much use of them. He was well known as a liberal benefactor to numerous charitable institutions, especially to hospitals, and was for many years one of the registrars of the Royal Literary Fund. His mental and bodily activity were extraordinary, and to use the words of one of his oldest friends,—“He had thoroughly lived out his life, and had found time and means to crowd into short intervals of business more kindly and generous deeds than would make the staple of many ordinary men's lives.”

BENJAMIN DENNISON NAYLOR died on the 27th of December, 1868, after a few days' illness, at his residence The Knoll, near Altrincham, Cheshire. He was the last lineal male descendant of four of the clergy ejected from their livings by the Act of Uniformity in 1662. He was a governor of Chetham's Hospital and Library, Manchester, by right of descent from Humphrey Chetham the founder, who died in 1653; an institution in the management of which he took an active and benevolent interest to the end of his life. He had been many years a Fellow of the Royal Astronomical Society, and was warmly attached to all scientific pursuits, particularly to astronomy and mechanics. He took constant pleasure in his observatory, which he had fitted up with a very fine equatoreal by Cooke of York. Mr. Naylor was also an old member of the Archæological Association.

EDDOWES BOWMAN was born in November 1810. On leaving Hazlewood School, near Birmingham (conducted by the now well-known Messrs. Hill), he entered an iron-foundry, with a view of following the engineering profession. Afterwards he undertook the management of some coal and iron works in Wales, and here the duties imposed on him were fulfilled with scrupulous exactness and to the entire satisfaction of the proprietors. A large portion of his leisure time was devoted to the moral and intellectual improvement of the people with whom he was connected, and by whom he soon became most highly respected. It was here, perhaps, that the peculiar aptitude for teaching developed itself, which characterised him through life.

After a few years thus spent, his tastes took a decided turn in favour of classical literature, and, in order to pursue his studies to greater advantage, he entered Glasgow University, where he took his degree of M.A. He then went to Germany, and studied with great earnestness under some of the most distinguished professors there.

Soon after his return to England, the chair of Greek and

Latin Classics and Greek and Roman History, in Manchester New College, became vacant by the resignation of Mr. F. W. Newman, and Mr. Bowman was then appointed to fill that office, which he did with earnestness, exactness, and thoroughness, until the College was removed to London in 1853.

From this time, without abandoning his favourite classical studies, he seems to have imbibed an increasing taste for natural science, which he pursued in its chief branches till his death, devoting much time and labour to the acquirement of the most recent knowledge in astronomy, optics, heat, electricity, acoustics, &c. These studies he pursued with his accustomed assiduity, not simply from the pleasure he derived from them himself, but that he might be better able to impart the knowledge of them to others; and, to enable him to do this more perfectly, he not only purchased the best apparatus obtainable, but spent much time and ingenuity in constructing numerous diagrams and contrivances for his lecture illustrations. His mode of lecturing was easy and fluent, and his language singularly clear and lucid.

Though astronomy was only one among a number of different branches of science cultivated by Mr. Bowman, yet his deep interest in this particular subject was evinced by the fact that, in a new residence erected some years ago, an observatory formed an important feature, and was constructed expressly to receive a new $7\frac{1}{4}$ -inch equatoreal, made for him by Messrs. Cooke and Sons, of York.

It was always a pleasure to him to show this fine instrument to his friends, though his other avocations did not permit him to make so much use of it himself as either he or others could have wished.

Mr. Bowman was elected a Fellow of this Society in 1864. He died July 10, 1869.

As Signor VERTU was little known beyond the circle of his professional duties, a few words of information concerning him may prove interesting. He was born in the valleys of the Vaudois in Piedmont, and was educated at the university of Lausanne. It was there, while under the tuition of the celebrated mathematician, Emman Devey, that he began to take an interest in Astronomy; he became very fond of the science, and was possessed of some good instruments, but his time being almost absorbed by his professional duties, he sent but one contribution to the Society, which is to be found in Vol. xxiii. of the *Monthly Notices*. He died at his residence, 40 Cromston Street, Derby, on the 22nd of July, 1869, after a short illness.

PROCEEDINGS OF VARIOUS OBSERVATORIES.

Royal Observatory, Greenwich.

The chief special work which has occupied the attention of the Astronomical Department of the Royal Observatory during the past year has been the preparation of the new Seven-year Catalogue of Stars for 1864, good progress of which has already been reported. The calculations are now completely finished, and about one-third of the Catalogue is printed; the whole work being intended to form an Appendix to the *Greenwich Observations* for 1868. We believe that its publication will be a great boon to all practical astronomers, especially as the Catalogue contains a large number of stars which have not before been observed at Greenwich since the time of Bradley.

Although the preparation and the reading of the proof-sheets of the new Seven-year Catalogue have formed the chief additional work of the Royal Observatory during the past year, absorbing necessarily a considerable portion of the computing strength; yet the ordinary observations and computations have not suffered seriously. The Sun, Moon, the principal planets, the minor planets in the first half of the lunation, the necessary stars for the determination of the clock and instrumental errors, with others whose places are required for special purposes, have all been observed with the Transit-Circle with the utmost regularity. Observations of the Moon, and of the stars and collimator, have also been daily made with the altazimuth when practicable.

The printing of the astronomical part of the volume for 1868 is in a very forward state, and the reduction of the observations made in 1869 is so far advanced that a considerable portion of the results is nearly ready for the printer.

The volume for 1868 will contain three Appendices:—1. Mr. Breen's paper, "On the Corrections of Bouvard's Elements of the Orbits of *Jupiter* and *Saturn*." 2. The Greenwich Seven-year Catalogue for 1864. 3. A Description, with Plans, of the Great Equatoreal.

Royal Observatory, Edinburgh.

The observations of fifty-five stations of the Meteorological Society of Scotland have been computed here during the last year, and published by the Registrar-General in Scotland. Time-signals by gun and ball have been daily given. Meridian observations of stars with the Transit Instrument and Mural Circle have been carried on, but not to the full extent, on account of the reduction of past observations having been taken up. A

Report to the Board of Visitors appointed by Government was published last May, and refers to several matters of exceptional interest.

Radcliffe Observatory, Oxford.

The principal change during the past year to be noted with regard to this Observatory is in its personal staff, arising from the death of the first assistant, Mr. A. Quirling. Mr. Quirling had been suffering from severe illness for several months before his death, which occurred on the morning of the 8th of June last. The vacancy which occurred in the establishment on this account, has been filled up by the appointment of Mr. Lucas to be the principal assistant, and by the engagement of Mr. S. Béchaux, B.A. of Sidney Sussex College, Cambridge.

Mr. Béchaux took first-class mathematical honours in the year 1861, and the energy and zeal with which he has devoted himself to the active duties of astronomy since his connexion with the observatory, has been already productive of the happiest effects.

The illness and death of Mr. Quirling of course produced some derangement in the business of the establishment, but not to so great an amount as might have been anticipated, as will be shown by the work which has been accomplished during the last year.

It may be mentioned, in the first place, that the volume of the Radcliffe observations for 1866, was published last midsummer, and that the astronomical portion of the volume for 1867 is nearly completed, some copies of the Catalogue of Stars (1477 in number) for that year having been circulated amongst astronomers.

The reductions of the observations for 1868 are nearly completed. The meridional observations for that year include a catalogue of about 1700 stars, 114 observations of the Sun, 63 of the Moon, 27 of *Mercury*, and 18 of *Venus*. Seven occultations of stars by the Moon were made and reduced, and the heliometer was used when the weather permitted for the observations of double stars.

For the year 1869, the transits are thoroughly reduced and ready to be made into ledgers for the formation of a catalogue of stars, in number about 1400, but only the first steps of the reduction of the North Polar distances have been performed. The number of meridional observations made during the year is quite equal to the average, the number of transits being about 3000, and of zenith distances about 4000. The usual quantity of extra-meridional work was also done in the year.

The photographic meteorology has been carried on by Mr. Lucas with the same success as heretofore, and the reductions for 1867 are nearly completed.

But the most remarkable work which has been completed during the year is the Second Radcliffe Catalogue of Stars which has very recently been finished, and some copies distributed amongst astronomers. As this Catalogue will have a separate notice in the general review of Astronomy for the past year, it will be sufficient in this place to say that it contains 2386 stars observed between the years 1854 and 1861, both inclusive.

Cambridge Observatory.

The meridian observations with the transit instrument and mural circle were made in the usual order until July 10th, when the former instrument was dismantled in preparation for the reception of the new Transit-Circle. These were chiefly confined to observations of standard stars for the determination of clock and instrumental errors, of *Mars* near opposition, and of the Sun near the equinoxes and solstices. Since July 10th, the time has been approximately found by transits taken with the telescope of the mural circle. Winnecke's comet was observed on thirteen separate nights in May and June with the Northumberland equatoreal; on each night it was compared with several stars carefully selected from catalogues. The results are found to be very accordant. Both the equatorials have been used in observing occultations.

The meteorological observations have been made at the usual hours of 9 A.M. and 3 P.M.

The courses of a few meteors were registered in August, but the sky was unfavourable in November.

Steady progress has been made during the year with the calculations and preparations for the press; the observations of more than 1000 stars, which were made in 1864 and 1865 with the Northumberland equatoreal, by means of the square bar micrometer, for the purpose of completing the Markree zones, have been reduced, and the mean places obtained for the beginning of 1865.

The observations of Winnecke's Comet have been reduced, and the comet observations of former years are now being arranged for the press. The transit reductions are completed. The mural circle reductions are completed to the end of 1866.

All the preparations have been made for some time past for the new Transit-Circle, the arrival of which has been most unaccountably delayed, as in October last it was expected.

Glasgow Observatory.

The operations at the Glasgow Observatory during the past year have been essentially the same as those of preceding years. In addition to stars chosen from the usual list, several of the minor planets have been observed with the transit circle. The Ochtertyre equatoreal has been employed in observing such of the minor planets as may be conveniently seen with it, and do not come within the range of the meridian instrument. A few observations of Brorsen's and Winnecke's comets have also been obtained with the same instrument.

True time continues to be transmitted in the usual manner to the city and port of Glasgow. A system of meteorological observations, conducted by means of self-recording instruments, was established at the observatory in the beginning of 1868 under the auspices of the Meteorological Committee of the Royal Society, and has continued since in active operation.

Work done with the Photoheliograph at the Kew Observatory.

The first instalment of the measurements and reductions of the Kew Sun-pictures taken during the two years 1862 and 1863, containing also the areas of the observed groups and an explanation of the methods followed in the working out of the observations, has been published in the last volume of the *Transactions of the Royal Society*. Nearly 150 separate copies of the paper, printed partly at the private expense of Mr. Warren De La Rue, were distributed, chiefly to foreign observatories, scientific institutions, and distinguished astronomers and physicists.

The second instalment, containing the heliographic positions of the Sun-spots observed from the beginning of 1864 to the end of 1866, is nearly ready, and will be presented to the Royal Society at an early date during the present session.

Some investigations were also made last year on the influence which a refracting medium of considerable density would have on the apparent size and figure of the Sun, and the time of rotation, as calculated from spots at different latitudes. The preliminary discussion has led to the conviction that a comparison of the times of rotation, as derived from spots while they are near the limb, with those deduced from the same spots when near the centre, will throw much light on several important questions connected with solar physics. The matter will be exhaustively investigated in the general discussion of the Kew results.

During the present year it is intended to bring, if possible, the work of the measurements up to date. The scarcity of spots during 1867 and 1868 was such, that the pictures of these years

may be measured in a comparatively short time; and it is hoped that, by completing, by the end of this year, the observations made up to at least the end of 1869, that the greater part of the succeeding years may be devoted to as careful a discussion of the whole work as is required by the importance of the astronomical and physical problems involved in it.

Messrs. De La Rue, Stewart, and Loewy, state that the reductions of Hofrath Schwabe's observations are now finished. By comparing his observations with those taken by Carrington, and also with the Sun-pictures taken at Kew, they arrived at very favourable conclusions regarding the accuracy of the delineations of the distinguished German observer. Beginning with the year 1832, they have measured the spotted area of all his pictures up to the time when Carrington's series commenced. From the results obtained they have, first of all, deduced fortnightly views, and in the next place, in order to get rid of the more transitory fluctuations, they have taken a series of those monthly views corresponding to the middle and end of each month, from the beginning of 1832 till the end of May 1868. Putting these results into a graphical form, they have obtained a curve exhibiting only the irregularities of comparatively long periods, and from the curve by the ordinary method of equalisation, they have deduced an equalised curve exhibiting the decimal period of solar disturbances.

They find therefrom the following epochs of maximum and minimum spotted area:—

Minimum	Nov. 28	1833
Maximum	Dec. 21	1836
Minimum	Sept. 21	1843
Maximum	Nov. 14	1847
Minimum	April 21	1856
Maximum	Oct. 7	1859
Minimum	Feb. 14	1867

From these dates it will be perceived that (as has been already observed) the time between the minimum and maximum is always less than that between the maximum and next minimum.

It will also be noticed that the whole period is not always of uniform length; nevertheless, judging from what has gone before, they believe that they are perhaps entitled to conclude that the approaching minimum will not be delayed much beyond the end of this year. It ought also to be remarked that, in all the three series, the progression from maximum to minimum is not a simple progression, but exhibits in each case traces of a secondary maximum.

Finally, they have examined these results for traces of the action of the planets upon Sun-spots, and pursuing the method indicated in their preliminary researches, they derived the fol-

lowing table, as exhibiting the evidence deduced from all the observations between 1832 and 1868:—

Relative Planetary Separation.	Excess or Deficiency of Spotted Area. Jupiter and Venus—Mars and Mercury.	
Between 0° and 30°	+ 881	+ 1675
30 „ 60	— 60	— 139
60 „ 90	— 452	— 1665
90 „ 120	— 579	— 2355
120 „ 150	— 705	— 2318
150 „ 280	— 759	— 1604
180 „ 210	— 893	— 481
210 „ 240	— 752	+ 547
240 „ 270	— 263	+ 431
270 „ 300	+ 70	+ 228
300 „ 330	+ 480	+ 1318
330 „ 0	+ 1134	+ 2283

From this table there appears to be an excess of solar activity when either *Jupiter* and *Venus* or *Mars* and *Mercury* are together, and a deficiency when they are 180° apart. We see also that the progression of the numbers is regular in each case and very similar in the one case to what it is in the other.

Stonyhurst College Observatory.

The principal building of this Observatory stands on slightly elevated ground in the centre of the college garden. It was built in 1838 for astronomical and meteorological observations.

The ground-floor consists of a central octagon, 22 feet across, with four transepts, each 10 feet by 8 feet, at the four points of the compass. Over the centre of the octagon is a circular room, surmounted by a revolving cylindrical roof, 10 feet in diameter. This upper room was built for an achromatic by Jones, equatorially mounted, of 4-inch clear aperture, and 5 feet 6 inches focal length. A meridian circle, by the same optician, was placed in the east transept, and another transit occupied the west transept. The diameter of Jones's meridian circle is 2 feet 6 inches; the telescope having an object-glass of 3 feet 6 inches focal length, and 3 inches aperture. Two sidereal clocks were also procured for the Observatory.

In October, 1850, the Rev. A. Weld determined very accurately the longitude of Stonyhurst by means of three of Shepherd's chronometers, the old observatory at Liverpool being chosen as the station of comparison.

Longitude of Stonyhurst	$9^{\text{m}}. 52^{\text{s}}. 68$ W. of Greenwich.
Latitude of Stonyhurst	$53^{\circ} 50' 40''$ N.

In 1867 the Observatory underwent a considerable change. The 8-inch Equatoreal, which formerly belonged to Mr. Peters, was purchased by the college authorities, and a special building erected for its reception. This new observatory was placed at a considerable distance (75 yards) from the old one, for fear lest otherwise the massive iron pier on which it rests might disturb the magnets suspended in the subterranean portion of the principal building.

A circular room, 24 feet in diameter, with a revolving dome, a transit-room of 10 feet square, containing an instrument by Cary of 3 feet focal length and $2\frac{3}{4}$ inches aperture, and a study 10 feet by 12, to be devoted to spectroscopic researches, form the whole of the new observatory. The foundations of the pile for the equatoreal have been constructed with the greatest care. A bed of concrete, 10 feet square and 2 feet thick, rests on a natural foundation of coarse growing sand. On the concrete are placed four dressed stones side by side, forming a square, and each weighing more than 10 cwt. These four stones support an hexagonal column, 5 feet 6 inches in diameter, each layer of which is composed of six large cut stones, and the whole is finished with a Yorkshire landing 4 inches thick. The total height from the gravel bed to the levelling screws of the instrument is about 17 feet. Underneath the floors of the building are ceiled cellars in which a hot-water apparatus has been fitted up for protection in damp weather. The support of the telescope is an iron pier cast in two pieces; viz. a foot which weighs 13 cwt., and a pillar weighing 17 cwt. The two are fastened together by iron nuts, which allow a little play in azimuth, and the foot rests on eleven blunt levelling screws.

The object-glass, made by Troughton and Simms, has a clear aperture of 8 inches, and 11 feet 6 inches focal length. The diameter of the N.P.D. circle is 2 feet 2 inches, whilst those of the R.A. and hour-angle are each 1 foot 7 inches. The engineer who mounted the telescope was Napier, but the fixings of the N.P.D. circle are by Cary. The clockwork, which is perhaps the most perfect portion of the instrument, requires winding only every six hours. It goes excellently, and has no strain upon it, since it serves only to regulate the motion, the motive power being a weight suspended within the iron pier.

The telescope is well provided with eye-pieces and micrometers; the highest power is about 750.

The dome, which covers the instrument, runs on twelve 6-inch rollers working freely between an upper and lower surface of railway metal. The flange of the upper railway metal is bolted to the sole plate of the dome. The framework of the dome is of pitch-pine, and out of the sole plate circular ribs converge to the zenith. The frame is stiffened with a reticulation of hoop-iron, and covered with $\frac{1}{2}$ -inch boards of pitch-pine. The outside is protected by a covering of painted canvass, and the internal finish is of American cloth of a dark colour. The whole

is moved by a spur wheel and pinion, gearing into a segmental rack, which rests on the wall plate. The wheel is actuated by a chain. This is so placed as to be directly opposite the shutter, and therefore generally near the observer's hand. The shutter consists merely of a frame of pitch-pine, covered outside with painted canvass, and inside with American cloth. It is worked by pulleys and bevel gearing, and its width is 4 feet 6 inches.

During the past year considerable advance has been made towards rendering the observatory practically complete. A stone pier has been erected on a brick foundation in the open air, and an equatoreal mounting attached to it. This mounting can be used for any tube, but it is principally intended for a $7\frac{1}{2}$ -inch Newtonian, with which the heavens can be freely swept without the necessity of moving a large dome. The two observatories have been connected by an underground wire to avoid the necessity of daily observing clock stars with two transit instruments and to have a sure check on the time at either observatory. A direct vision spectroscope has been adapted to the equatoreal by Browning. In the summer six compound prisms were procured from Hoffman of Paris, and these are being mounted for a spectroscope by Troughton and Simms. A hot-water apparatus has been arranged for the protection of the equatoreal dome and the adjacent rooms. Two observing-chairs have also been made for the large telescope. And, lastly, a new 8-inch object-glass has been ordered from Dallmeyer, the present glass not being considered sufficiently good for the excellent mounting of the instrument.

The work done has so far been mostly of a tentative character. Observations of the Moon's surface, measures of the diameters of planets and of the distances between double stars, Winnecke's comet, the November meteors, and some preliminary work with a direct-vision spectroscope, constitute the miscellaneous observations of the last twelve months. Correct time for the magnetic and meteorological self-recording instruments being a want continually felt, no fine night is allowed to pass without clock-stars being observed.

The meteorological observations, made with instruments that have been carefully compared at Greenwich or at Kew, extend in an uninterrupted series over twenty-three years.

In 1866, Stonyhurst was chosen as one of their three English meteorological stations by the Board of Trade, and was provided accordingly with self-registering barometer, thermometers, and anemometer. These instruments arrived in December 1867, and hourly readings, as also the maxima and minima of the curves traced by them, have been taken here since January 1, 1868. Both the curves and the readings are forwarded weekly to the Central Observatory at Kew.

A monthly summary of the results obtained with the meteorological instruments has been printed for private circulation during the past ten years, and a table of the reduced monthly

magnetic observations is now added to the yearly meteorological means.

The magnetic department is at present the most complete portion of the observatory. A continued series of monthly determinations of the dip, horizontal force, and declination, extend over somewhat more than six years. These have been reduced this year for the purpose of calculating the annual inequalities, &c. Previous to 1863, when a small chronometer was replaced by Frodsham's No. 3148, only occasional observations were made with the dip circle, No. 32 of Barrow, and Jones's unifilar, purchased in July, 1858; but these scattered results are of considerable use for finding the secular variation of the magnetic elements. A suitable building in a retired part of the college garden has been erected for these instruments.

During the long vacations of 1868 and 1869, a magnetic survey of the whole of France has been made with the Stonyhurst magnetic instruments, and at the expense of the college authorities. The results of the survey of the west of France, made in 1868, were presented to the Royal Society in June last, and the more numerous series of observations taken in 1869, in the east of France, are at present in process of reduction.

In 1866 a grant was made by the Royal Society towards the expense of a set of self-recording magnetographs for this observatory. In consequence, two subterranean chambers were built adjoining the old observatory. One is a photographic room, 15 feet by 12 feet. The other, a chamber 20 feet by 18 feet, in the centre of which stand the pillars supporting the three magnetographs, with two additional pillars holding telescopes, by which the observer is able to read, at any moment, the state of the magnets without interfering with the continuous photographic record. This last room is well guarded against all damp or variation of temperature. The roof is arched, with two rings of brick set in blue lias lime, and the whole covered with 6-lb. lead, and then with earth and gravel. The walls are three in number. The inner one is a single brick wall set in hydraulic lime. Surrounding this is a cavity for air 3 inches wide, with air-holes 1 foot apart, all round the room. Enclosing this is a rubble wall, 2 feet thick. And at the outside of all, as a protection from the surrounding earth, is 1 foot of loose rubble, which serves admirably for drainage. The flagged floor is built upon piers, and is thus raised 18 inches above the sand. Owing to these precautions the room keeps remarkably dry, and the temperature may be considered almost constant.

Continuous photographic records have been obtained of the declination, and of the two components, horizontal and vertical, of the intensity since January, 1868. The curves traced during the magnetic storms, which were coincident with the grand auroral displays of April and May last, were of the most perfect description, a disturbance of more than $2^{\circ}.5$ in 9 minutes, having been clearly recorded in the Declination Magnetogram. Some

of the curves have been compared with those of Kew, and also with those of Signor Donati of Florence, with very interesting results.

Mr. De La Rue's Observatory.

During the past summer and autumn, numerous experiments have been made to render the luminous prominences of the Sun visible, when that luminary is not totally eclipsed. In order to effect this object, films of gold and other metals have been interposed between the 13-inch mirror and the eye-piece; and fluid coloured media have been also employed for the same object. These experiments will be again resumed during the present year.

An investigation is also being carried on, having for its object the production of a true parabolic figure, with greater certainty than has been obtainable by any of the methods hitherto used in making specula for reflecting telescopes.

Mr. Lassell's Observatory.

Mr. Lassell remarks that since his return from Malta, he has almost entirely neglected astronomy; but he has at length re-erected his two foot equatoreal, nearly as it was at Starfield, and at Bradstones. He has chosen the form of a drum-dome, as possessing greater permanence of shape; and therefore affording greater facility of opening and shutting, without danger of the shutters being set fast by increased or unequal friction by warping. Mr. Lassell thinks that the greater capacity of the building is also advantageous, by its securing a more uniform temperature. The dome revolves on six eight-inch cannon-balls, working between cast-iron channels, the sectional curvature of which is six inches radius. The lower channel is screwed to a ring consisting of two strata of inch and a half deal plank, eleven inches broad, cut into lengths of three feet six inches, and bolted together with the end joints alternating. This ring is secured by half-inch bolts, built in the brickwork, to a nine-inch circular wall, whose interior radius is fourteen feet six inches. The upper channel is screwed to the under surface of a similarly constructed ring, of pieces of plank *three* inches thick. This forms the base ring of the dome, on which are supported three other lighter rings by intervening crosses, these lighter rings and crosses being respectively made out of inch, and inch and a quarter plank. Across the circle of the uppermost ring, but two feet six inches from its centre, is laid a trussed beam, twenty-nine feet eight inches long, which carries the side-supports of the horizontal shutter, distant four feet eight inches, and extending quite across the building. This shutter, about eighteen feet long, travels on rollers between these supports, and when withdrawn, exposes the vertical sky from the circumference of the dome to two feet six inches beyond the

centre. The roof, principally borne by the trussed beam, and having no more inclination than is necessary for carrying off the rain, is covered (as well as the circumference of the dome) with three-eighth inch deal board in two strata, which finally received a coat of well-painted canvas. The vertical shutter is framed of wood to the radius of the building, travelling on two large pulleys guided by a rail, and when opened, slides within that part of the dome which is adjacent to the opening on the preceding side, so as to be completely out of the way, and unaffected by wind, however violent.

The mode of carrying on the dome while observing, is by attaching a light pair of three-sheave blocks to the wall-plate and base-ring, the end of the rope, or fall being carried to a hook or belaying-pin attached to the observing staircase. The facilities for opening and closing the dome are by this construction eminently satisfactory, either operation being performed in *less than one minute*, without any irksome exercise of muscular power.

Mr. Lassell has also introduced a slight variation in the *mounting* of the telescope, having substituted a cast-iron frame for the mass of masonry which formerly supported the upper part of the polar axis; which renders the instrument more capable of removal, should that ever be required.

He is glad to say that the condition of the telescope on this remounting gives him the greatest satisfaction. The speculum has been laid up under a coat of varnish for more than eight years; yet on this being carefully dissolved off with a little absolute alcohol, the surface reappears with no sensible deterioration of either lustre or defining power; and Mr. Lassell sees minute points of light and the surface of *Jupiter* (barring a little abatement of his own visual acuteness) just as well as ever. He is inclined to think this size of telescope the very best in point of efficiency that can be, since it is just within the power of one observer to manage it, without being dependent on an assistant.

Mr. Lassell is afraid that he cannot promise for the future to be a very active observer; and during the few opportunities he has yet had, he has been most struck with the phase of *Jupiter*, which presents this year an aspect more distinguished by a profusion of narrow sharp belts, together with on the whole a more uniform aspect from day to day and from week to week, than used formerly to be present. On reference to a pretty numerous series of sketches of the planet which Mr. Lassell has made during more than twenty years, he is struck with the variety of configuration which has presented itself, without precisely the same form having hitherto recurred. When we reflect upon the magnitude of these colossal changes on the surface of a planet of so vast a size, we cannot help being impressed with a feeling of intense admiration, and of curiosity (if that were of any avail) to know how they are produced.

Mr. Huggins' Observatory.

In the autumn of 1868, numerous experiments were made for the purpose of finding a method by which the forms of the solar prominences could be observed directly. Several new arrangements of the spectroscope were constructed with this object in view, but at last the very simple method of employing a wide slit suggested itself, and on Feb. 13, Mr. Huggins succeeded in this way in observing *directly*, and not by inference, from the varying length of the bright lines, the outline of a solar prominence. When a spectroscope of only moderate power is employed, Mr. Huggins found it to be of advantage to limit the field of view of the little telescope to the part of the spectrum where the light of the prominence is situated, and further to interpose a red glass when the light is found to be inconveniently bright to the eye.* Other experiments were carried on for the purpose of rendering the solar prominences visible without a spectroscope, by means of the property of selective absorption possessed by many-coloured media, a method which presented itself to Mr. Huggins three or four years since. The problem to be solved was to find a combination of media which would absorb light of all refrangibilities except precisely that of C., or of F. A large number of mineral and vegetable substances was examined; the most promising combination which has been found consists of a solution of carmine in ammonia which cuts off nearly all the light more refrangible than C., combined with a solution of chlorophyll which gives a band of absorption, taking away the brighter part of the light less refrangible than C. As yet chlorophyll has only been obtained in a state in which the band of absorption encroaches upon C., and weakens the light of the prominence.†

The observations in this observatory were interrupted in the autumn by the necessary preparations to fit the building for the reception of a refractor of 15 inches aperture, which is being constructed by Mr. Grubb of Dublin, for the Royal Society, by whom it will be placed in the hands of Mr. Huggins.

* *Proceedings Royal Society*, vol. xxvii. p. 302.

+ *Monthly Notices*, vol. xxx. p. 36.

NOTES ON SOME POINTS CONNECTED WITH THE PROGRESS OF ASTRONOMY DURING THE PAST YEAR.

Discovery of Minor Planets and Comets.

In the last Annual Report a record was made of the discovery of the unprecedented number of twelve asteroids during the year 1868. In this respect, the planetary additions in 1869 contrast very unfavourably with those of the preceding year. The general cloudy state of the sky during the last twelve months has interfered sensibly with delicate astronomical observations of all kinds, and none more so than with those of the minor planets and similar faint objects. However, during occasional intervals of clear weather, two of these minute bodies have been added to the asteroid list; ⁽¹⁰⁸⁾ *Hecuba*, discovered on the 2nd of April 1869, by Dr. R. Luther, at Bilk; and ⁽¹⁰⁹⁾ *Felicitas*, on the 9th of October, by Dr. C. H. F. Peters, at Hamilton College, Clinton, New York.

Several of the minor planets discovered in 1868 have received their distinctive names since the date of the last Report, a record of which may be useful in this place. They are ⁽⁹⁹⁾ *Dike*, ⁽¹⁰⁸⁾ *Hera*, ⁽¹⁰⁴⁾ *Clymene*, ⁽¹⁰⁵⁾ *Artemis*, and ⁽¹⁰⁶⁾ *Dione*.

Three telescopic comets have been detected during the past year. The most important is Comet I. 1869, known also as Winnecke's periodical comet. This object had been identified at a previous perihelion passage with a comet discovered by Pons in 1819. According to a recent paper by M. Oppolzer, inserted in the *Astronomische Nachrichten*, we gather that there are very strong grounds for believing that it is also identical with a comet discovered by M. Pons so far back as 1808. M. Oppolzer, however, hopes to be able to speak more definitely on this point when he has completed some additional investigations on the comet's orbit, on which he is now engaged.

The two remaining comets — Comet II. 1869, and Comet III. 1869 — were both discovered by M. Tempel, of Marseilles, the first on October 11, and the second on November 27. Several observations have been made of each at different observatories and approximate elements of their orbits have been computed.

Proposed Prizes for the Discovery of Comets.

The Fellows will be glad to learn that the *Imperial Academy of Sciences at Vienna*, acknowledging the importance of continuous cometary investigations, especially in connexion with

observed streams of meteors, has proposed to give a series of prizes, limited to eight annually, for the discovery of telescopic comets during the three years' interval between May 31, 1869, and May 31, 1872. The prizes will be awarded at the annual meeting of the Academy, which usually takes place at the end of May, and will consist either of a sum of money,—twenty Austrian ducats—or of a gold medal of equivalent value. In a circular distributed among astronomers, the Academy has published a series of rules for the guidance of the discoverers. From its principal clauses, it appears that the comet must be invisible to the naked eye at the time of discovery, and also one whose appearance could not have been predicted with any degree of certainty. Notice of the discovery must be immediately sent to the Academy at Vienna either by post or telegraph, without waiting for further observations. The message must, however, always be transmitted by telegraph when practicable. The authorities of the Academy undertake to communicate the discovery immediately to the principal observatories. The prize will not be awarded to any discoverer of a comet which has not been observed by another astronomer unless his first record of the comet's place is supplemented by further observations, sufficient in number for the determination of the elements of the orbit.

The Council are glad to hear that the *Imperial Academy of Sciences at Vienna* has thus so generously determined to encourage a systematical searching for telescopic comets, a branch of astronomical discovery which has been comparatively neglected of late years. They trust that the initiative taken by the Vienna Academy will be heartily responded to, not only by the Continental astronomers, but by the Fellows of this Society, many of whom are now so well furnished with the necessary instruments for cometary observations.

Division of Labour in Computing Ephemerides of the Minor Planets.

Observers of the minor planets are now practically dependent upon the *Berliner Jahrbuch* for the annual ephemerides of these objects. The rapid increase in their number renders it necessary to make a distribution of labour among computers, to allow of proper provision being made for the computation of the tabular places. The Fellows may, therefore, be interested to know by whom the important work which appears in the pages of the *Berliner Jahrbuch* is accomplished. The following list gives the names of the computers, and the planets for whose tabular places for 1870 each is responsible :—

M. Adolf	Helena, Mnemosyne.
Dr. Albrecht	Sappho.
Dr. Anderson	Undina.

Dr. Auwers	Circe.
Dr. Von Asten	Cybele, Diana, Egeria.
Dr. Becker	Amphitrite, Beatrix, Clotho, Erato, Eugenia, Europa, Hygeia, Niobe.
Dr. Bruhns	Bellona, Irene.
Dr. Brunn	Isis.
Dr. Celoria	Clytie.
Dr. Deike	Thisbe.
Dr. Dunér	Panopea.
Dr. Engelmann	Eurydice.
Dr. Gunther	Ægina, Calliope, Calypso, Daphne, Euterpe, Galatea, Lætitia, Massilia, Phoea, Urania.
Mr. Hall	Terpsichore.
M. Hoek	Proserpine.
M. Karlinsky	Hestia.
Dr. Kowalczyk	Hesperia.
Dr. Krüger	Themis.
M. Lehmann	Eunomia, Metis, Minerva, Vesta, Victoria.
M. Leppig	Aurora, Flora.
M. Leveau	Hera.
M. Liegel	Lutetia, Pomona.
Dr. Lorek	Semele.
Dr. R. Luther	Danaë, Hebe, Melete, Parthenope.
M. Möller	Pandora.
Nautical Almanac	Pallas
Dr. Oppolzer	Angelina, Concordia, Olympia.
Dr. Peters (Altona)	Sylvia.
Dr. Peters (Clinton)	Echo, Feronia, Frigga, Ianthé, Io, Miriam.
Dr. Powalky	Aglaia, Doris, Fortuna, Freia, Harmonia, Nysa, Pales, Virginia.
M. Prey	Ariadne.
Mr. Safford	Alcmene.
Dr. Schultz	Alexandra.
Dr. Schur	Arethusa, Melpomene.
M. Sievers	Atalanta, Leucothea, Polyhymnia, Psyche, Thalia.
M. Stark	Hecate.
Dr. Stolz	Asia.
Dr. Tiele	Fides.
Dr. Tietjen	Ausonia, Leda, Nemausa.
Dr. Tischler	Eurynome.
Dr. Valentiner	Clio.
M. Vogel	Ægle, Antiope.
M. Westphal	Euphrosyne.
M. Wolfers	Ceres.
M. Wolff	Julia, Leto.

The Total Solar Eclipse of August, 1869.

This eclipse was successfully photographed in America, by two of the eclipse parties organised, on the proposal of Prof. Coffin, superintendent of the *Nautical Almanac* of the United States, by Prof. H. Morton, of Philadelphia, who took charge of these expeditions. It was also photographed by Commander Ashe, director of the observatory at Quebec.

The apparatus employed by the American astronomers was similar in principle, but of larger optical power, than that used by De La Rue in Spain, in 1860, that is to say, the principal image was enlarged by a Huyghenian eye-piece before it reached the sensitive plates. The adoption of this form of apparatus was decided upon "after a careful study of De La Rue's reports and pictures, as also those of the late expeditions," which led Prof. Morton to the conclusion that the plan of enlargement presented many advantages over that of making the photograph directly in the principal focus of the telescope; one of these advantages consists in the superior definition of the position-wires over that which obtains when they are situated within the focus of the telescope, as in the form of instrument used by Major Tennant. Certain modifications in the form of the Huyghenian eye-piece were made by Mr. Zentmayer, in order to adapt it specially for the photographic work, and the instantaneous slide was also somewhat different from that used by De La Rue. The telescopes employed in taking the photographs possessed a great advantage in respect of aperture over the Kew Heliograph, being 6 inches in diameter, whereas the object-glass of the Kew instrument is only 3·4 inches in diameter; moreover, in the instruments used in the American expeditions, the primary image of the Sun is enlarged only to about two inches in diameter, whereas in the Kew Heliograph the image is enlarged to 3·8 inches, so that during totality, when the full aperture of the objective was employed as in both cases in the Kew Heliograph, the area-ratio of the objective to that of the picture was as 0·8 to 1, whereas in the American telescope it was as 9 to 1, or about 11·25 times greater. Six pictures were taken during the totality at Burlington, $40^{\circ} 48' 17''$ N.L., and $0^{\text{h}} 56^{\text{m}} 14^{\text{s}}$ west of Washington; and four at Ottumwa, situated about 75 miles west of Burlington, by another party. The totality pictures at Burlington were obtained with exposures of from 5 to 7 seconds, and those at Ottumwa in from 6 to 16 seconds. In 1860, De La Rue's first picture was obtained with an exposure of 60 seconds; on taking into consideration the relation of aperture to size of picture, the Burlington pictures would represent an exposure of 56·25 to 78·75 seconds, and the Ottumwa 67·5 to 180 seconds in the Kew Heliograph. It does not, therefore, appear that any step has been made in the sensitiveness of

the chemicals since 1860, or that the luminosity of the protuberances greatly differed in 1869 from that in 1860.

The American pictures are very perfect specimens of astronomical photography; and have the advantage from the relative shortness of the exposure of showing the state of the phenomena in reference to a given epoch with more precision than was possible in 1860. By comparing together the photographs obtained at Burlington and Ottumwa, it is seen that the protuberances are absolutely identical in both series except in so far as they are more or less covered in consequence of the parallax displacement of the lunar disc. They also show that those brilliant surroundings of the Sun, not bounded by such distinct outlines as the protuberances, and yet whose forms are clearly distinguishable, are identical in both series of the photographs. This goes to confirm the photographic observations of De La Rue in 1860, and Tennant and Vogel in 1868, showing that the protuberances properly so called do not constitute the sole surroundings of the Sun's photosphere, but that a portion at least of the coronal brightness belongs also to the Sun. On the occasion of this eclipse, it was noticed by Prof. Pickering, who accompanied one of Prof. Morton's parties to Mount Pleasant, that, while "the sky was strongly polarised all around, close up to the corona, that object itself was not a source of polarised light." It will be recollected, on the contrary, that during the total eclipse of 1868, it was observed both in Egypt and India that the light of the corona was strongly polarised. On future occasions this apparent discrepancy will undoubtedly receive such attention as it may be hoped will lead to a true solution.

Several photographs of the partial phase were obtained with beautiful definition. At Burlington, a record of the first contact was procured; and at Ottumwa, a picture at the last instant, just before totality, which gives a photographic record of the phenomenon known as Baily's beads, being, as Prof. Morton remarks, "simply the last glimpse of the Sun's edge cut by the peaks of lunar mountains into irregular spots." The pictures of the partial phase all show an increase of light on the solar surface in contiguity with the limb of the Moon, as was observed by De La Rue in 1860. Prof. Morton was at first inclined to attribute this to the existence of a lunar atmosphere; but subsequent experiments have led him to conclude that the cause is entirely chemical, and does not correspond to any celestial phenomenon; an analogous appearance is frequently to be seen in terrestrial photographs. It has been suggested by Mr. Stone, that there is a possibility of its being at least partially due to the scattering of the Sun's light which falls on the Moon's edge at a grazing angle, and that part of the light scattered is superadded to the direct light of the Sun near the Moon's limb.

Commander Ashe obtained four photographs of the totality at Jefferson Town, with an 8-inch equatoreal, the pictures being taken in the principal focus of the instrument. These pictures,

although they do not possess the sharpness of the American photographs, confirm what has already been stated in regard to the identity of form preserved by the protuberances and the entities with soft outlines; unfortunately in photographs 3 and 4, there is evidence of the disturbance of the telescope during the exposure of the sensitive plate.

Atmospheric Dispersion.

The Astronomer Royal has employed his great theoretical and practical knowledge of optics to correct the unpleasant, and for delicate observations, fatal effects of atmospheric chromatic dispersion at low altitudes. By providing prisms of different angles the mean effects of the chromatic dispersion can be entirely destroyed. In the *Monthly Notices* for January, an ingenious and simple method of applying a prism of varying angle has been described. It is certain that with eye-pieces of this construction, the difficulties in making delicate observations at low altitudes will be diminished.

Spectrum Analysis.

Our Fellow, Mr. Lockyer, has pursued with great diligence and success his spectroscopic researches on the Sun. Since the last Report he has found that several other substances besides hydrogen are occasionally to be detected above the photosphere, namely, sodium, barium, magnesium, and iron. The presence of the bright lines of these substances rising above the photosphere, and associated with the bright lines of hydrogen, Mr Lockyer regards as indicating a state of disturbance of the solar matter, greater than was present at the time of his earlier observations. From a slight alteration in refrangibility of the bright lines of hydrogen, as shown by their want of perfect coincidence with the corresponding lines of absorption, Mr. Lockyer believes that he has evidence of rapid currents in the solar matter, sometimes attaining a velocity of 40 miles per second in a vertical direction, and a velocity of 120 miles per second in a horizontal or cyclonic direction. He considers that his observations support the conclusion that "the chromosphere and the photosphere form the true atmosphere of the Sun, and that, under ordinary circumstances, the absorption is continuous from the top of the chromosphere to the bottom of the photosphere." In these observations Mr. Lockyer is accumulating a store of facts, upon which we may hope to base a more complete theory of the constitution of the Sun than we now possess.

In the early part of last year Mr. Huggins, by the simple method of using a wide slit, afforded a means of observing directly the forms of the prominences.

Zöllner has proposed a new form of spectroscope, in which the

light of a star is divided between two prisms, each half of the light being refracted in an opposite direction. By this means small differences in position of stellar and solar lines appear doubled in amount, and can be observed, therefore, and measured with great accuracy. Zöllner, by using a wide slit, has made careful observations of the forms of the solar prominences, and of the rapid changes which take place in them. His observations confirm the conclusions as to the very great mobility of the matter of the red flames which had been previously arrived at by Janssen and Lockyer from the rapid changes they had observed in the bright lines of these objects.

Mr. Plummer observed successfully the spectrum of the Aurora Borealis in April 1869. His observations agree with the previous spectroscopic examination of this object by Angström and Struve.

Spectroscopic observations of the Aurora have also been made by Prof. Winlock.

Father Secchi has continued his spectroscopic researches on the Sun and stars. They are described in the *Comptes Rendus*.

Lunar Radiation.

The thermo-electric pile has been employed by more than one observer during the past year in experiments upon lunar radiation, and with some success. By means of the "three-foot" Parsonstown reflector, a thermopile, and a Thomson's reflecting galvanometer, a second thermopile being also connected with the galvanometer to compensate for disturbing effects, the Earl of Rosse succeeded, during the lunations of March and April 1869, in obtaining evidence of lunar heat increasing in amount with the phase of illumination. The manifested heat-rays were, however, shown to be principally obscure; and Lord Rosse hence infers that the greater part of the heat received from the Moon consists of solar heat that has been first absorbed by the lunar crust, and then given off in dark radiation. No evidence of cosmical heat was obtained. By comparison of the solar and lunar actions upon the pile, a vessel of hot water being used as an intermediate standard of reference, it was estimated that the relation of solar to full-Moon radiation is as 89819 to 1, a proportion sensibly the same as that arrived at by a purely theoretical investigation. By the use of a cistern of hot water, with a blackened exterior, exposed to the pile under similar circumstances to the Moon-lit surface of the great mirror, Lord Rosse found that the amount of deviation which the full Moon caused in his galvanometer appeared to indicate an elevation of temperature of the lunar surface through 500° Fahrenheit.

Some later observations have been made upon the same subject in Paris, respectively by M. Baille, at the Ecole Polytechnique, and M. Marié-Davy at the Paris Observatory. The

former employed a concave mirror of 39 centimetres aperture to condense the Moon's rays upon his pile, and also made use of a Thomson's galvanometer. The one conclusion at which he arrived was, that the full Moon, at Paris and in the summer months, gave as much heat to his pile as a radiating surface 6.5 centimetres square, maintained at boiling-water temperature and placed at a distance of 35 metres. M. Marié-Davy has published results of two series of measures secured during the lunations of October and November last. The first were made with a pile attached to a 9-inch equatoreal refractor, the second with an 8-inch mirror; the object-glass in the former case having been found to intercept a large proportion of the heat-rays. M. Marié-Davy's measures confirm those of Lord Rosse. They show that the heating effect of the Moon increases with the illumination of the visible disk. Between October 9, when the Moon was four days old, and October 20, when it was full, the measured heat of the condensed beam of moonlight increased from $0^{\circ}.00017$ (Centigrade) to $0^{\circ}.00287$. If this last number be divided by the ratio of the area of the concentrated image to the area of the object-glass, we have twelve-millionths of a centigrade degree as the direct heating power of the full Moon at the Earth's surface. This is the result given by the object-glass: that afforded by the mirror is about six times as great. It will be seen that M. Marié-Davy has converted his galvanometer indications into centigrade equivalents: how this conversion was effected, and how the constancy of the scale indications is secured, if it is secured, we are not informed. He confirms Lord Rosse's inference that the proportion of solar to lunar radiation is about as 80000 to 1, and likewise concludes that the Moon imparts to us no heat from an internal or cosmical source. Further, he infers that the diffusive power of the lunar surface is considerable, at least equal to that of the least coloured of terrestrial rocks; and he finds that the lunar heat by reason of its large percentage of obscure rays is far more impressionable by atmospheric humidity than that from the Sun.

It will be remembered that Professor Smyth, in his Teneriffe experiments, determined the heating power of the full Moon to be equal to one third of that of a Price's candle at a distance of 14 feet 9 inches. M. Marié-Davy finds that such a candle at such a distance affects his pile to the extent of $0^{\circ}.00075$ centigrade, which he conceives to be the heating power of the Moon upon the summit of Teneriffe, upon the supposition that the heat emitted by the respective candle-flames was sensibly the same.

Heating Power of the Stars.

The experiments upon this subject, commenced by Mr. Stone with the great Equatoreal of the Greenwich Observatory, in the year 1868, and mentioned in the last Annual Report, were continued

as weather permitted during 1869. In pursuing them, Mr. Stone was led to the construction of a thermopile which there is good reason to believe will prove of value in thermometric researches other than those of the class for which it was specially prepared. His early trials convinced him that it was almost impossible to distinguish the feeble currents generated by stellar heat from the grosser effects produced upon the pile by exposure of one face within the telescope tube and the protection of the other face outside the telescope tube. It was evident that to maintain the pile in thermal equilibrium its two faces must be exposed to precisely similar atmospheric influences. Mr. Stone therefore resorted to what in effect may be described as a horse-shoe pile, the two faces of which being similarly presented to the object-glass of the telescope were affected alike by disturbing causes, whether these took the form of draughts of air or cooling of the metals of the pile by radiation. By this arrangement the whole heat of a star's image cast upon either face of the pile manifested itself *per se*. Decided indications of heat from *Arcturus* and α *Lyræ* were thus obtained on several nights. The amounts were measured by a reflecting galvanometer; and by a somewhat tedious process the galvanometer indications were converted into Fahrenheit-scale equivalents. It was found that the heating effect of *Arcturus*, after allowing for absorption by the object-glass, was 0.00000137 of a Fahrenheit degree; that of α *Lyræ* being about two-thirds of this amount. Otherwise expressed, the heat from *Arcturus*, at an altitude of 25° at Greenwich, is about equal to that from a three-inch cube of boiling water at a distance of 400 yards, while from α *Lyræ* it is equal to that from the same cube at 600 yards. Mr. Stone conceives that the difference of heating power may be connected in cause with difference of colour. He finds that the manifested heat diminishes rapidly as the amount of moisture in the air increases, and that all sensible effect is cut off by the slightest cloud or haze. The details of the investigation are published in the *Proceedings of the Royal Society* for January, 1870.

Transit of Venus, 1874.

The preparatory arrangements for the observations of the transit of *Venus*, 1874, are sufficiently advanced to encourage us to expect most important additions to the data already collected for the determination of our fundamental astronomical unit of length. The British Government has already placed at the disposal of the Astronomer Royal sufficient funds for the equipment of five stations, each with an Altazimuth and Transit, for the determination of longitude and local time, and with two telescopes, one of which is to be of six inches aperture, and to be

provided with driving power. Four of the larger instruments have already been obtained, and the Transits and Altazimuths are in actual progress in the manufactory of Messrs. Troughton and Simms. The second telescope at each station will be of 4 inches aperture.

The present intention appears to be to place the British observers at Kerguelen's Island, Woahoo, Auckland in New Zealand, Alexandria, and Rodriguez.

A Commission, consisting of Admiral Paris, MM. Faye, Laugier, Villarceau, and Puiseux, has reported to the Bureau des Longitudes that it would be particularly desirable for the French astronomers to occupy the Islands of Saint Paul and Amsterdam, Yokohama, Tahiti, Nouméa, Mascate and Suez.

The North German astronomers have referred the consideration of the action which they should urge upon their Government, to a Committee, of whom the illustrious astronomer of Gotha was elected chairman.

This Committee appeared to lay great stress upon the employment of heliometers for fixing the relative position of *Venus* on the Sun at the different stations.

Equatorials with driving power for the eye-observers were to be of 6 feet focal length and 52 lines aperture. The employment of photography and spectroscopic observations was discussed. The chief objection to the employment of photography appeared to be in the question of expense, although Professor Argelander was not satisfied with the degree of accuracy which might be expected from it. The further consideration of this question was, however, deferred to a sub-committee. Spectroscopic observations were only proposed to indicate the approach of the planet for the observation of external contacts. The Committee recommended that the Government be urged to fit out four expeditions,—two to the North and two to the South. The stations specially referred to as favourable were, Nertschensk, Hohodadi, Kerguelen, Edwards', Crozet's, and Auckland Islands, and in certain respects Mauritius.

The Russian territories offer most valuable positions for the location of observers. These stations are certain to be well occupied by the Russian astronomers. The Director of the Imperial Observatory at Pulkova has already secured a Committee for the consideration of a proposition to establish a chain of observers across the country from Kamtschatka to the Black Sea, at intervals of about 100 miles. This appears desirable on account of uncertainties connected with the atmospheric conditions in the month of December.

It is to be hoped that, for the same reason, there will not be a too great crowding of the observers towards one or two points, in other regions, to the exclusion of others of nearly equal importance; and that, in this matter at least, after the best consideration has been given to the subject, we may all adopt instruments of not very unequal power, and attempt to make the same class of

observations in the same way. Uniformity in these observations means success; want of uniformity, comparative failure.

We would here recall attention to the beautiful series of maps by Mr. Proctor of the parts of the Earth turned towards the Sun at the principal phases of the Transit, which accompany his paper in the March Number. This paper contains a careful deduction from Mr. Hind's results in the *Comptes Rendus*, vol. liii. p. 131, of the chief stations for the observations of internal contact, deduced with direct and especial reference to that phase as the most important point of observation. On account of the nature of the motion of the planet relatively to the Sun, this exhibits in a more striking light than had previously been done, the value of Halley's method in the Transit of 1874.

Re-observations of the Stars down to the 9th magnitude in Argelander's Zones from N.P.D. 10° to 92° .

Dr. Auwers has lately distributed a catalogue of 539 stars to be used in connexion with the proposed re-observation on the meridian of stars within the zones of N.P.D. 10° and 92° down to the 9th magnitude. This re-observation has been recommended by the German Astronomical Society. The scheme states that sufficient accuracy will be obtained by two observations of each star. Each observation to be taken over three or four wires, and the circle readings to be made with two microscopes. The work has been distributed amongst thirteen observatories. One zone, that from N.P.D. 35° to 40° , alone remains unappropriated.

34 *Messier.*

Dr. O. A. L. Pihl has lately republished with additions his paper on this cluster which originally appeared in the Supplementary *Monthly Notices*, for 1868. With an equatoreal of only $4\frac{1}{4}$ inches aperture, he has found an interesting and useful field of investigation by laying down the relative positions of 85 stars in this cluster. The positions are fundamentally referred to two principal stars as zero points, and very considerable accuracy appears to have been obtained. A re-examination of this cluster at some future time, and a comparison with Dr. Pihl's positions, may lead to important results.

The Newton-Pascal Forgeries.

"L'Examen de la Discussion soulevée au sein de l'Académie, par M. Leverrier," contains a complete exposure of the falsehood of the Newton-Pascal papers which M. Chasles was induced by the skill of an artful forger to communicate in such profusion

to the French Academy. M. Leverrier deserves great praise for the combination of talent, scientific skill, and zeal in the cause of truth which proved so efficient in finally destroying this imposture. However, the first indisputable astronomical proofs of the falsity of these documents are contained in the two letters which Prof. Grant of Glasgow addressed to M. Leverrier on September 12, 1867, and October 31, 1867, and which were published without delay in the *Comptes Rendus*.

Prof. Grant's objection of the identity of the so-called results of the masses, &c. of the planets with the corresponding results contained in the third edition of the *Principia*, was unanswerable.

We may thus assert that, in conjunction with that of his distinguished friend, Sir David Brewster, the name of our Fellow, Prof. Grant, will ever remain most honourably connected with the exposure of the Newton-Pascal imposture.

The Great Newall Telescope.

The 25-inch equatoreal telescope, commenced several years ago by T. Cooke & Sons, of York, for R. S. Newall, Esq., of Gateshead, is now so far completed that it has been removed from the works at York into its observatory in Mr. Newall's grounds, at Ferndene.

The general design and appearance is the same as that of Cooke's well-known equatoreals on the German principle improved; but the extraordinary size of all the parts has necessitated the special arrangement of most of them.

The length of the tube, which is of riveted steel plates, including dew-cap and eye-end, is 32 feet, and it is of cigar shape; the diameter of the object-end being 27 inches, and the centre of the tube 34 inches. The cast-iron pillar supporting the whole is 19 feet in height from the ground to the centre of the declination axis, when horizontal; and the base of it is 5 feet 9 inches in diameter. The trough for the polar axis weighs alone 24 cwt.: the weight of the whole instrument being nearly 9 tons.

The object-glass has an effective aperture of 25 inches (nearly). In order as much as possible to avoid flexure from the unequal pressure of the object-glass, it is made to rest upon three fixed points in its cell, and between each of these points are arranged three levers and counterpoises round a counter-cell, which act through the cell direct on to the glass, so that its weight in all positions is almost equally distributed among the 12 points of support, a slight excess being thrown upon the 3 fixed ones. The focal length of the object-glass is 29 feet. A Barlow lens is arranged to slide on a brass framework within the tube. The hand is passed through an opening in the side of the tube, and by means of a handle attached to the cell the lens may be pushed into or out of the cone of rays.

Attached to the eye-end of the tube are two finders, each

having an object-glass of 4 inches aperture; they are fixed above and below the eye-end of the main tube, so that one may be readily accessible in all positions of the instrument. It is also supplied with a telescope having an object-glass of $6\frac{1}{2}$ inches aperture. This is fixed between the two finders, and is for the purpose of assisting in the observations of comets and other objects for which the large instrument is not so suitable. This assistant telescope is provided with a rough position circle and micrometer eye-pieces, and is illuminated by Cooke's new illuminating apparatus.

The driving clock is in the upper part of the pillar, and is of comparatively small proportions, the instrument being so nicely counterpoised that a very slight power is required to be exerted by the clock, through the tangent screw, on the driving wheel (7 feet diameter), in order to give the necessary equatoreal motion. The clock is regulated by a pendulum, the intermittent motion of which is converted into a continuous one by the peculiar and ingenious arrangement of a double train of wheels, invented and exhibited to the Society by the late Mr. T. Cooke; with the exception that a fan, revolving in an air-box, the sides of which are perforated with holes at regular intervals, alternately opened or closed by the action of the clock as it goes faster or slower, is substituted for the double spring which acted as a brake, a most elegant contrivance, first, it is believed, employed by the late M. Foucault.

The declination axis is of peculiar construction, necessitated by the weight of the tubes and their fittings, and corresponding counterpoises on the other end, tending to cause flexure of the axis. This difficulty is entirely overcome by making the axis hollow, and passing a strong iron lever through it, having its fulcrum immediately over the bearing of the axis near the main tube, and acting upon a strong iron plate rigidly fixed as near the centre of the tube as possible, clear of the cone of rays. This lever, taking nearly the whole weight of the tubes, &c., off the axis, frees it from all liability to bend.

The hour-circle on the bottom of the polar axis is 26 inches in diameter, and is divided on the edge,* and read roughly from the floor by means of a small diagonal telescope attached to the pillar; a rough motion in right ascension by hand is also arranged for by a system of cog-wheels moved by a grooved wheel and endless cord at the lower end of the polar axis, so as to enable the observer to set the instrument approximately in right ascension by the aid of the diagonal telescope.

The declination and hour-circles will be illuminated by Geisler's tubes, and the dark and bright field illuminations for the micrometers will be effected by the same means.

Mr. Norman Lockyer, who had an opportunity of examining

* The hour-circle is also divided on the face, and read by micrometer microscopes.

and trying this magnificent instrument shortly before its despatch to its owner Mr. Newall, speaks in the highest terms of its mounting and mechanical arrangements generally; and so far as he was able to judge of its optical performance, with the low power to which the state of the weather restricted him, he considered it to be very promising.

The difficulties attending the constructing and mounting of so large an object-glass are exceedingly great. That all these then have been entirely overcome no one conversant with the refinements involved can reasonably expect, and the optical and mechanical perfection of the famous Cooke factory has raised the standard by which telescopes are judged. We have every hope that this instrument will be worthy of their fame.

This record of enlightened private enterprise would be incomplete if we did not add that Mr. Newall proposes, when the instrument is properly fixed in a good climate, to place it at the disposal, for a certain number of hours in each day, of any qualified astronomer who desires to use it. The benefit likely to be rendered to science by Mr. Newall's liberality can hardly be overrated. We understand that his observatory is to be under the direction of Mr. Albert Marth. We have not yet heard that its site has been finally decided on; it is certain that the full powers of such a telescope cannot be called forth in the climate of England.

Mr. Buckingham's Telescope.

In connexion with this splendid accession to observational astronomy, we would call attention to the existence of a telescope not much inferior in size to that just described, which was constructed some years ago by Mr. J. Buckingham, a Fellow of this Society, and which was exhibited by him at the International Exhibition of 1862. Its clear aperture is $21\frac{1}{4}$ inches, and its focal length $28\frac{1}{2}$ feet. It is mounted as an equatoreal of the (so called) German form. Mr. Buckingham has also constructed another telescope of 9 inches aperture, mounted equatorially. Competent judges, who have been permitted to visit Mr. Buckingham's Observatory at Walworth, speak in the highest terms of the completeness and ingenuity of the arrangements. It is understood that Mr. Buckingham has employed a method, peculiar to himself, of practically correcting the aberrations of the large object-glass. Regarding its optical performance we have as yet no definite report. Mr. Buckingham is known to be not only a mechanician of great originality, but also an industrious observer. It is very much to be desired that he should find leisure from his arduous occupations to give to the world a com-

plete account of his optical processes, of the contrivances peculiar to his instrumental mountings, and of the performance and produce of the magnificent apparatus which he has created with so much labour.

Zenith Sectors for Indian Survey.

One of the zenith Sectors constructed for the Great Trigonometrical Survey of India, by Messrs. Troughton and Simms, from Colonel Strange's designs, has been despatched, and has reached its destination, Bangalore, in the Madras Presidency. It went out by the Overland route under charge of Lieut. Rogers, R.E., an officer of the Survey, and is said to have sustained no injury in transit. This instrument has a telescope of 4 inches aperture and 4 feet focal length. The sectors are portions of a circle 3 feet in diameter; they are read by four micrometer microscopes, illuminated by a simple light somewhat in the manner employed in the transit-circle of the Royal Observatory. It is furnished with the appliances of a zenith telescope, and can be used, therefore, as such if desired. The instrument is to be employed in the observation of latitudes on the southern portion of the great meridional arc of India at short intervals, with the twofold object of investigating the very interesting physical question of local attraction, and of eliminating the effects of such attraction on the geodetic determination of the figure of the Earth. These operations have been intrusted to Capt. J. Herschel, R.E.

Mr. Carrington's Observatory.

All who are interested in Astronomy will be glad to hear that our Fellow, Mr. Carrington, whose valuable observations of circumpolar stars and of Sun-spots are well known, is now engaged in erecting a new observatory at Churt, near Farnham. This observatory is arranged on a new plan of construction. As it is situated on a conical hill, entirely detached, and 60 feet high, no elevation of the building is needed. Mr. Carrington has sunk the observatory below ground, so that the instruments can just be directed over the soil at the top of the mound. There has been sunk a dry well, 6 feet in diameter, to a depth of 40 feet, in which a clock, placed in an air-tight case, may be kept at a position of invariable temperature and at a constant and diminished pressure. The observatory will be furnished with an Altazimuth on Steinheil's principle, in which the horizontal axis is also the optical axis; an object-glass of 6 inches, provided with a prism fixed outside it, is placed at one end, and the eyepiece at the other end of the axis.

We hope this observatory, when it is completed, will speedily be as well known for the valuable contributions to astronomy proceeding from it as Mr. Carrington's former observatory at Redhill.

Second Radcliffe Catalogue of Stars.

We have to record the publication by the Radcliffe Observer of a second catalogue consisting of 2386 stars, deduced from observations extending from 1854 to 1861. The observations were made with the transit instrument and the meridian circle, by Jones, the use of which has been discontinued since the establishment of the Carrington circle in 1861. This circumstance made it desirable to embody in a distinct catalogue the observations made with those instruments.

The stars contained in the Catalogue have been, in general, observed many times, and their places may therefore be considered to be fixed with the greatest accuracy. Mr. Main has instituted a most careful examination between the right ascensions of the principal stars and those given in the Greenwich Seven-year Catalogue for 1860. From this comparison corrections have been deduced and applied to the Radcliffe results, in order to reduce this Catalogue to the same fundamental epoch as that of the Greenwich Catalogue. A similar comparison has also been made between the resulting north polar distances of these catalogues, and a slight systematic discordance appears between the results which has been attributed, with great probability, to outstanding uncorrected errors of division in the circles.

The magnitudes assigned to the stars are in most cases deduced from observation, the number of estimates on which the final result being based is given in a separate column.

In the introduction it is stated that the whole of the work connected with the formation of the Catalogue has been made by Mr. Main and one assistant Mr. Luff.

Pulkova Observations.

The observations made with the Transit Instrument of the Pulkova Observatory, from 1842 to 1853, have been printed in two magnificent volumes, and distributed for the use of astronomers. The first volume contains a full and most interesting Introduction by the illustrious Director, Mr. Otto Struve, giving an account of the methods adopted and observations made for the determination and elimination of the errors of the instrument and of its position. In the same volume there is a Catalogue of the Mean Right Ascensions of 348 Stars reduced to the epoch 1845, with star-constants for two epochs, 1840 and 1870.

Chinese Astronomy.

The Assistant-Secretary, Mr. Williams, has presented to the Society a MS. work, entitled, *Comets observed in China from B.C. 613 to A.D. 1640*. These observations have been extracted from Chinese works of authority, and are given with the original text. They are translated and arranged chronologically, with a full explanation of the several asterisms, described as occurring in the path of the comets. They are preceded by some introductory remarks in which the progress of Chinese astronomy is traced from between two and three thousand years before the Christian era to the present time. There is also an Appendix, containing chronological and other tables, required in the reduction of Chinese time to our reckoning, the construction and use of which tables are fully explained in the Introductory remarks, with numerous examples of their application. To facilitate the identification of the asterisms mentioned in the observations, a Chinese celestial atlas has been constructed, traced from an original work on astronomy. In this the thirty-one divisions into which the Chinese divide the visible heavens are laid down separately with the stars composing them, according to our nomenclature.

*Communications to the Society from February 1869 to
February 1870.*

1869.

- Mar. 12. Observations of the Transit of *Mercury*, 1868. Sir T. Maclear.
 Ditto ditto Mr. Abbott.
 Ditto ditto Mr. Barneby.
 Occultations observed at Liverpool. Mr. Joynson.
 On the Solar Eclipse of August 7, 1869. Mr. Hind.
 On the Aden and Guntour Photographs of Eclipse, 1868.
 Mr. De La Rue.
 Note on the Attraction of Ellipsoids. Mr. Cayley.
 On the Meteoric Shower, Nov. 1868. Sir T. Maclear.
 On the Transit of *Venus*, 1874. Mr. Proctor.
 Rotation of *Mars*. Mr. Proctor.
 On an extensive Train of Sun-spots. Mr. Browning.
 On an Improved Mode of Mounting Finders. Mr. Browning.
 On the Observations of the Transit of *Venus*, 1874.
 Mr. Airy.
 Personality in the Determination of the Line of Collimation in a Transit. Mr. Stone.

- April 9. On the Determination of Longitude by the Electric Telegraph. Commander Ashe.
 Note on an Aurora Borealis, April 2, 1869. Mr. Plummer.
 On the Problem of the Determination of a Planet's Orbit from three Observations. Prof. Cayley.
 Description of an Improved Driving-Clock. Mr. Kincaid.
 On some Effect of the Comparative Clinging of the Limb of *Venus* to that of the Sun in the Transit of 1874, as compared with that of 1882. Mr. Stone.
 On the Practical Speed of Electricity through 7200 Miles of Land Wire. Mr. Davidson.
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 On Personality in Observing Transits of the Limb of the Moon. Mr. Dunkin.
- May 14. Opposition of *Mars*.
 On a Method of Imitating the Transit of an Inferior Planet. Mr. Hollis.
 On Mr. Joynson's Paper of Occultations. Mr. Plummer.
 On the Solar Eclipse of August 1869. Mr. Paine.
 Determination of the Direction of the Meridian with a Russian Diagonal Transit Instrument. Capt. Clarke.
 On a Sun-spot observed May 1, 1869. Mr. Bidder.
 Probable Error of Greenwich Observations in Zenith Distances estimated by Discordances from the Separate Means. Mr. Stone.
 Observations of Winnecke's Comet. Mr. Wortham.
 On the Period of η *Argûs*. Prof. Loomis.
 On ditto ditto Mr. Tebbutt, Jun.
 On the Transit of *Venus*. Mr. Proctor.
 On a Sun-spot, March 14, 1869. Mr. Browning.
 On the Preparations desirable for Photographic Observations of Phenomena such as Transits of *Venus*. Col. Tennant.
 Comments on the Preceding Paper. Mr. De La Rue.
 On the Solar Eclipse of 1871. Col. Tennant.
 Observations of Winnecke's Comet. Rev. S. Perry.
- June 11. Theory of the Tides. Mr. Ogilvy.
 Occultations of Stars by the Moon. Mr. Joynson.
 Note on the Transit of *Venus*, 1874. Mr. Hind.
 On the Distribution of the Nebulæ. Mr. Proctor.
 On the Nature of certain Appearances in Sun-Spots. Mr. Brayley.
 On a simple form of Star Spectroscope. Mr. Browning.
 Note on Lambert's Theorem. Mr. Cayley.
- Nov. 12. Note on the Floor of *Plato*. Mr. Birt.
 Selenographical Notes, *Apennines*, and Adjacent Regions. Mr. Weston.
 Lunar Eclipse of July 23, 24, 1869. Mr. Tebbutt.
 On his New Observatory at Churt, Surrey. Mr. Carrington.

Occultations observed at Leyton. Mr. Talmage.
The November Star Shower, 1869. Mr. A. S. Herschel.

On some attempts to render the red prominences visible.
Mr. De La Rue.

On the Solar Eclipse, 1869. Commander Ashe.

On a change in Colour in the Equatorial Belt of *Jupiter*.
Mr. Browning.

On the Application of Photography to determining the
Solar Parallax from Transits of *Venus*. Mr. Proctor.

On a Method of imitating the Transit of a Planet over
the Sun. Rev. Dr. Robinson.

On the Solar Eclipse of 1869. Mr. Paine.

American Photographs, Total Solar Eclipse of 1869.
Rev. T. W. Webb.

Dec. 10. Observations of the November Meteors, 1869. Lieut.
Tupman.

Chinese Astronomy. Mr. Williams.

Determination of the Orbit of a Planet from Three
Observations. Prof. Cayley.

On Annual appearances and their connexion with the
Phenomena of Terrestrial Magnetism. Mr. B. Stewart.

A Method of constructing Charts by which in a few
moments the great circle course between any two
points may be accurately ascertained. Mr. Proctor.

1870. A New Theory of the Milky Way. Mr. Proctor.

Jan 14. Observations of Meteors, Nov. 13, 1869, in America.
Mr. Davidson.

Observations of *Jupiter's* Satellites. Mr. Joynson.

On a Bright Cross Micrometer for measuring the posi-
tion of lines in faint Spectra. Mr. Browning.

Occultation of Stars by the Moon. Captain Noble.

Summary of Sun-spot Observations made by the Kew
Photo-Heliograph during 1869. Messrs. De La Rue,
Stewart, and Loewy.

Seventh Catalogue of Double Stars observed at Slough,
1823-1829 inclusive, 84 of which had not been pre-
viously described. Sir John Herschel.

List of Public Institutions and of Persons who have contributed to the Society's Library, &c. since the last Anniversary.

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ADDRESS

Delivered by the Chairman, Professor J. C. Adams, on Presenting the Gold Medal of the Society to M. Charles Delaunay.

Gentlemen,—It has been announced to you that the Society's Medal has been awarded to M. Ch. Delaunay for his great work on the Theory of the Moon.

The illness of our excellent President having made it impossible for him to be present on this occasion, the Council have done me the honour to request that I would occupy the chair, and in his stead lay before you the grounds of their award. I have acceded to their wishes with the more readiness because I have given some attention to special branches of the Lunar Theory, and my study of M. Delaunay's work has led me to form the highest opinion of its merits.

Of all the problems presented to us by physical astronomy none has so much engaged the attention of mathematicians as that of the determination of the motion of our satellite. The theoretical interest as well as the great practical importance of the results, has proved an irresistible attraction, and the mathematical difficulties have merely acted as a stimulus to the invention of various methods of surmounting them. It is fortunate that this has been the case, as the excessive labour involved in any theory of the Moon approaching to completeness, might otherwise have proved too great for human perseverance. The foundations of the theory were laid by Newton in his *Principia*; and although his investigations are only fragmentary, being simply intended to show

how some of the leading lunar inequalities may be deduced from theory, yet they form one of the most admirable portions of that immortal work. Towards the middle of the eighteenth century the theory was more systematically entered upon by Clairaut, D'Alembert, and Euler, who severally showed that the theory was competent to give very approximate values of all the inequalities which were then recognised by observation.

Still the theory was far from being sufficiently perfect to serve as a foundation for lunar tables accurate enough for the uses of navigation. This degree of accuracy was first attained by the tables of Mayer, who not only carried the approximations to the values of the coefficients of the various lunar inequalities further than his predecessors had done, but also corrected the theoretical coefficients thus obtained by comparison with his own observations. The theory was greatly advanced by Laplace, not only by his more accurate theoretical determination of the coefficients, but also by several important discoveries, especially that of the cause of the Moon's secular acceleration.

The improvements in the lunar tables, however, which were made successively by Bürg and Burckhardt, were founded, not on theory, but on comparison of the former tables with observations; and the empirical tables thus produced were far more accurate than any that could have been formed at that time by theory alone. Dissatisfied with this state of things, and wishing to see astronomy founded exclusively on the law of attraction, only borrowing from observation the necessary data, Laplace induced the Academy of Sciences to propose for the subject of the mathematical prize which it was to award in 1820 the formation, by theory alone, of lunar tables as exact as those which had been constructed by theory and observation combined. The prize was divided between two memoirs—one by M. Damoiseau, the other being the joint production of MM. Plana and Carlini. Damoiseau's memoir is printed in the third volume of the *Recueil des Savants Etrangers*. Plana's great work on the lunar theory, which appeared in 1832, is the development of the joint memoir by himself and Carlini. By these important works an immense advance was made in the theory, the approximations being carried to such an extent that the resulting coefficients were comparable in accuracy with those given by observation. In 1824 Damoiseau published tables founded entirely on his theory, which were found to be quite as exact as those of Burckhardt.

Both Damoiseau and Plana, following the example of Laplace, start from differential equations in which the Moon's longitude is taken as the independent variable; and after the equations have been integrated, they obtain the values of the Moon's co-ordinates in terms of the time by reversion of series. An important innovation, however, was introduced by Plana in the mode of conducting the investigation and exhibiting the results. The values of the Moon's co-ordinates being developed in series of sines and cosines of angles which vary uniformly with

the time, the coefficients of the several terms of these series will depend on the eccentricities of the orbits of the Sun and Moon, the inclination of the Moon's orbit to the plane of the ecliptic, the ratio of the mean motions of the Sun and Moon, and the ratio of their mean distances from the Earth. Now Damoiseau, in common with all previous writers, having assumed certain values of the quantities just mentioned as given by observation, contented himself with determining the numerical values of the coefficients. Although this is all that is required for the construction of tables, yet, from a theoretical point of view, it leaves the mind unsatisfied, inasmuch as any coefficient in its numerical form shows no trace of its composition, that is of the manner in which its value depends on the value of the assumed elements. The several coefficients are far too complicated functions of the elements to be represented analytically, except in the form of infinite series, and Plana, accordingly, develops these coefficients in such series, proceeding by powers and products of the eccentricities, the tangent of the inclination, the ratio of the Sun's mean motion to that of the Moon, and the ratio of the Moon's mean distance to that of the Sun, all these quantities being assumed to be small, and the last mentioned ratio, which is much smaller than the others, being considered as a quantity of the second order.

In this mode of development, the numerical factor which enters into any term of the coefficient of any of the lunar inequalities is an ordinary fraction which admits of being determined not merely approximately, but with absolute accuracy. It is easy to see what great facilities are afforded by this circumstance for the verification of the work by a comparison of the results obtained by different methods. The greater or less degree of approximation will thus depend on the greater or less number of terms taken into account in the several series.

The numerical values of the several elements are not substituted in the formulæ until the work is completed, and this is attended with the important advantage that when a comparison of the theory with observation has supplied more accurate values of the elements, their corrected values can be at once substituted in the same formulæ, without requiring any additional work.

On the other hand, if the numerical values of the elements be introduced into the calculations from the first, then if it is desired to introduce corrected values of the elements, much additional investigation will be required for the purpose.

No doubt the labour required in order to obtain a given amount of numerical accuracy by this method is very much greater than is required when each coefficient, instead of consisting of a series of terms, is reduced to a simple numerical quantity, but the great theoretical advantage of knowing the composition of every coefficient in terms of the elements well repays the additional labour.

The degree of convergence of the series obtained for the

several coefficients is in general sufficiently rapid, but in some few of the coefficients, on the contrary, the convergence is so slow, at least in the leading terms, that it is necessary to take into account terms which are analytically of a higher order than those to which the approximation is in general limited.

Thus Plana, who proposed to himself to determine the lunar inequalities completely to the fifth order, found it necessary in special cases to carry the approximation to the seventh and even to the eighth order, and in several cases he also added an estimated value of the remainder of the series founded on the observed law of diminution of the calculated terms.

Soon after the publication of Plana's great work, Sir John Lubbock formed the plan, which he partly carried out in his various tracts on the theory of the Moon, of verifying Plana's results by a totally different method, starting from differential equations in which the time is taken as the independent variable, and thus avoiding the necessity of reversion of series.

Later, M. de Pontécoulant undertook the same work on a similar plan, and carried it out more completely in the fourth volume of his *Théorie Analytique de Système du Monde*.

These works, while they corrected some errors which had crept into Plana's computations, confirmed their wonderful general accuracy, and with some few exceptions they do not extend the approximation beyond the order to which Plana restricts himself.

Meantime, M. Hansen had undertaken a completely new investigation of the lunar theory, by a remarkable method peculiar to himself and explained in his *Fundamenta nova investigationis orbitæ veræ quam Luna perlustrat*, which appeared in 1838.

In applying the method described in this work to the case of the Moon, M. Hansen throughout employs numerical values of the elements of the Moon's orbit, and consequently the coefficients of the lunar inequalities as obtained by him are also purely numerical. The process is one of successive approximations, which are repeated again and again until the values of the inequalities which are found from the last approximation sensibly coincide with those which were assumed in entering upon that approximation.

The numerical values of the coefficients thus finally obtained are undoubtedly very exact. The slight corrections which these coefficients still require are probably chiefly due to the small corrections required by the numerical elements on which the calculations are based, and in the method employed no provision is made for taking into account the effect of these corrections.

From his formulæ, M. Hansen constructed tables of the Moon, which were published in 1857, at the expense of the British Government; and these tables, having been found far superior in accuracy to all others, are now exclusively employed in the calculation of ephemerides.

A detailed account of the calculations leading to M. Hansen's

last approximation, was given by him in the two parts of his *Darlegung der Theoretischen Berechnung der in den Mondtafeln angewandten Störungen*, which severally appeared in 1862 and 1864.

After the great works, to which we have thus briefly referred, had been either completed or were in progress, it might have been supposed that the matter was exhausted.

Our Associate M. Delaunay, however, was not of this opinion. Having devised, so long ago as 1846, a perfectly original and singularly beautiful method of integrating the differential equations of the Moon's motion, he determined to apply this method to the complete re-investigation of the theory, and to carry on the approximation to a much greater extent than had been done by his predecessors. The principal fruits of his labours, to which he has devoted himself with almost unexampled perseverance for so many years, are contained in the magnificent volumes which the Imperial Academy of Sciences have done both M. Delaunay and themselves the honour of publishing among the volumes of their *Memoirs*. It is for this great work that your Council have awarded to M. Delaunay the Society's medal.

Strongly impressed with the advantages of determining the co-efficients of the lunar inequalities in the analytical form, both as affording a solution more complete in itself and more satisfactory to the mind, as well as one offering facilities for the comparison of the results of different investigations, M. Delaunay did not hesitate to follow the example set in this respect by M. Plana, notwithstanding the immense length of the necessary calculations. M. Delaunay's results are thus obtained in a form which makes them directly comparable with those of M. Plana, while the methods employed in obtaining them are wholly different.

M. Delaunay chooses the *time* as the independent variable, and takes as his starting-point the differential equations furnished by the theory of the variation of the arbitrary constants. In an able Memoir which appeared in 1833, Poisson had advocated the employment of these equations in the theory of the Moon's motion, and he applied them to the discussion of some special points of that theory. These equations had been long used, almost exclusively, for the determination of the perturbations of the planets, and they offer peculiar advantages in the treatment of the secular inequalities and those of long period. In the case of the Moon, however, in consequence of the large perturbations caused by the disturbing force of the Sun, the ordinary mode of integrating these equations by successive approximations soon leads into calculations of inextricable complexity. In fact, these equations give the differential coefficients of the several elliptic elements taken with respect to the time, in terms of the elements themselves. In the case of the planets, where the disturbing forces are so small compared with the predominant central force of the Sun, very approximate values of the disturbed elements may be found by substituting in the values of the differential coefficients,

the undisturbed instead of the disturbed values of the elements, and then integrating.

The perturbations of the elements thus found are said to be due to the first power of the disturbing force. If now the approximate values of the disturbed elements be substituted in the differential equations, and these be again integrated, we shall obtain a second approximation to the values of the disturbed elements, and the additional terms thus found are said to depend on the square of the disturbing force. In the theories of the planets it is only in special cases that terms depending on the square of the disturbing force need be taken into account, and it is scarcely ever necessary to consider terms of the next order of approximation.

In the case of the Moon, however, it would be necessary to repeat the process of approximation at least four or five times, in order to obtain results of the accuracy required in the present state of the theory. If we consider that the disturbing function consists of a great number of terms, and that each term gives rise to a corresponding term in the value of each of the disturbed elements, while powers and products of the corrections of all the elements in every possible combination, up to a certain order, have to be taken into account, it may be readily imagined how impracticable it would be by such a process to carry on the approximation to a greater extent than has been already done by Plana. Every process in which the approximations require to be repeated several times, is subject to the inconveniences that have been described, and these inconveniences are much greater when, as in the present case, we have to make successive approximations to the values of the *six* elements of the orbit, instead of to the values of the *three* co-ordinates of the Moon.

It was with the view of avoiding this excessive complication of the method of successive approximations that M. Delaunay devised his method of integrating the differential equations of the Moon's motion. The fundamental idea of this method consists in attacking the difficulty by small portions at a time, and in replacing these extremely complicated successive approximations by a much greater number of distinct operations, each of which is comparatively simple, so that it may be carried out to any degree of exactness that may be desirable, while the mind is relieved by being able readily to embrace the whole of each operation in one view.

It is difficult, without the use of algebraical symbols to give an idea of M. Delaunay's beautiful method, but I must endeavour, in some measure, to fulfil this task, and I must crave your indulgence should I fail in the attempt.

The theory of the variation of the arbitrary constants gives, as is well known, the differential co-efficients of the elliptic elements with respect to the time, in terms of the elements themselves and the partial differential co-efficients of a certain function, called the Disturbing Function, taken with respect to those ele-

ments. By a proper choice of elements, the differential equations may be reduced to their simplest, or to what is called their *canonical* form. In this form the six elements are divided into three pairs, the elements of each pair being conjugate to each other. Then the differential coefficient of any element with respect to the time is simply equal to the partial differential coefficient of the disturbing function taken with respect to the element which is conjugate to the former, the partial differential coefficients which occur in the two equations corresponding to a pair of conjugate elements being affected with opposite signs.

The disturbing function may be readily developed in a series of periodic terms involving cosines of angles, each of which is formed by the combination of multiples of the Moon's mean longitude, the distance of the Moon's perigee from its node, and the longitude of the node, together with angles which depend on the position of the disturbing bodies. The disturbing function likewise contains a non-periodic term, which, as well as the coefficients of the periodic terms, are all functions of the major semi-axis, the eccentricity and the inclination of the Moon's orbit.

Since the mean longitude of the Moon involves the time multiplied by the mean motion which is a function of one of the elements, it is obvious that the differentiation with respect to this element will give rise to terms in which the time occurs without its being included under a sine or a cosine. Such terms would render the equations very inconvenient for the determination of the lunar inequalities; and M. Delaunay accordingly avoids the introduction of them by taking the mean longitude itself instead of the *epoch* of mean longitude, as one of his elements, while by the simple yet novel expedient of adding to the disturbing function a non-periodic term which is a function of the major semi-axis alone and is independent of the disturbing forces, he preserves to the differential equations the same very simple form which they had at first. After this modification of the disturbing function, the time no longer enters into it explicitly except in so far as it is introduced by the values of the co-ordinates of the disturbing bodies, and consequently the difficulty which was before met with completely disappears.

The six elements employed by M. Delaunay are thus,—the Moon's mean longitude, the distance of the perigee of its orbit from the node, and the longitude of the node, which for distinction may be called the three *angular* elements, and three other elements which are respectively conjugate to the former, and which are determinate functions of the major semi-axis, the eccentricity and the inclination of the orbit.

The three co-ordinates of the Moon at any time are given in terms of the three angular elements and of the quantities last mentioned.

Now let us imagine, for a moment, that the disturbing function contained no periodic terms, but was reduced simply to its non-periodic part. Consequently the partial differential co-

efficients taken with respect to the angular elements would all vanish, and therefore the three conjugate elements would be all constant, as well as the major semi-axis, the eccentricity and inclination, of which those elements are functions. Hence, again, the partial differential co-efficients taken with respect to the conjugate elements would be functions of those elements, and would therefore be constant. Hence each of the angular elements would consist of an arbitrary constant and a term proportional to the time, the multiplier of the time in each case being a known function of the three constant elements.

The object of M. Delaunay's method is, by means of a series of changes of the variables, to cause all the more important periodic terms to disappear from the disturbing function, one by one, while the differential equations continue to retain their canonical form, so that after each transformation we approach more nearly to the conditions of the ideal case which has just been considered.

In order to effect any one of these transformations, M. Delaunay supposes, for the moment, that the disturbing function is reduced to its non-periodic part, together with one of the periodic terms selected from among those which have the greatest influence in producing the lunar inequalities. With this simplified form of the disturbing function, the equations admit of being easily integrated. The elements with which we start may thus be expressed in terms of three new angular elements which vary uniformly with the time, and three new constant elements. M. Delaunay shows how the constant elements may be so chosen that they may be considered as respectively conjugate to the three new angular elements, so that, in fact, the quantities which are multiplied by the time in the expressions of these angular elements are respectively equal to the partial differential co-efficients of a function of the new constant elements taken with respect to these elements.

Having thus found the relations between the old set of elements and the new ones by means of the simplified form of the disturbing function, M. Delaunay now restores the complete value of that function, and chooses new elements which are connected with the old ones by exactly the same relations as in the case just considered. Of course the three new angular elements will no longer vary uniformly with the time, and the three elements respectively conjugate to these will no longer be constant.

When, by means of the proper formulæ of transformation, the new variables have been substituted for the old ones in the disturbing function and in the expressions of the Moon's co-ordinates, M. Delaunay shows that—

1st. One of the important terms of the disturbing function disappears, viz., the periodic term which was selected in the preliminary investigation.

2nd. Various inequalities corresponding to this term are introduced into the values of the three co-ordinates of the Moon.

3rd. The values of the six new variables in terms of the time

are determined by differential equations of exactly the same form as those which determined the values of the six variables for which they have been substituted.

One of the periodic terms having been in this manner caused to disappear from the disturbing function, a new operation of exactly the same kind causes another term of this function to disappear; similarly a third term may be taken away by means of a third operation, and so on to any number of terms.

In this way, after a suitable number of operations of this kind have been effected, the disturbing function will have been simplified by the removal from it of its most important periodic terms, after which the further process of integration becomes simple enough to be treated in the same manner as if we were concerned with the perturbations of a planet or of the Sun.

The whole difficulty in the determination of the lunar inequalities is caused by the great magnitude of the disturbing force of the Sun. M. Delaunay has therefore at first confined his attention to the investigation of the irregularities which are produced by this disturbing force, and the two magnificent volumes before us are entirely occupied with this investigation. Thus he has provisionally left out of consideration the very small inequalities due to some secondary causes, such as the attraction of the planets and the figure of the Earth; and, besides, he has omitted to consider the perturbations of the Sun's apparent motion about the Earth, intending in a supplementary volume to take into account the effects due to these several causes.

By means of repeated applications of the beautiful method of transformation which I have above attempted to describe, M. Delaunay proceeds to get rid of all the periodic terms of the disturbing function due to the Sun's disturbing force, which are capable of producing inequalities in the co-ordinates of the Moon of an order inferior to the fourth. For this purpose fifty-seven such operations are required to be performed. When these have been effected, the periodic terms which remain in the disturbing function are so small that their powers and products may be neglected, and consequently the differential equations which determine the six elements last introduced in terms of the time, may be integrated at once. Since the values of the Moon's co-ordinates are known in terms of the elements just mentioned and the time, we have only to substitute the values of the elements that have been found, in order to determine the Moon's co-ordinates in terms of the time.

The values of the elements, however, that would be found in this way are very complicated, and therefore the substitutions which would be required in order to find the Moon's co-ordinates would be excessively long. M. Delaunay, accordingly, prefers to get rid of the remaining periodic terms in the disturbing function, one by one, by means of transformations exactly similar to those which have been already effected. In order to carry on the approximation to the extent which he desires, M. Delaunay finds it necessary to perform no less than 448 of these secondary

operations, but each such operation becomes very simple, since the squares of the coefficients of the periodic terms under consideration may be neglected.

Thus, at length, by means of 505 transformations, all the periodic terms of the disturbing function are removed, and the problem is reduced to the ideal case which was considered at the outset of our account of M. Delaunay's method.

After each transformation, by making the proper substitutions in the expressions for the Moon's co-ordinates, those co-ordinates are obtained in terms of the system of elements last introduced, so that finally the three co-ordinates are known in terms of the three final constants and angles which vary uniformly with the time.

It has been already mentioned that Plana, in his great work on the Lunar Theory, determined the analytical values of the coefficients of the lunar inequalities as far as terms of the fifth order inclusive, and that he only carried on the development to a greater extent in cases where the slowness of the convergence of the series appeared to him to render it necessary to take into account terms of higher orders than the fifth.

M. Delaunay has proposed to himself to carry on the approximation so as to include all terms of the seventh order, and in cases where the series converge slowly to take into account terms of the eighth, and even of the ninth order.

Those who have had any experience in calculations of this nature will readily understand how enormously the labour required has been increased by thus adding two orders more to those which Plana has considered. It is not merely that the terms of higher orders are far more numerous than those of the lower, but also that each of the terms of the former kind is much more difficult to calculate, since it arises from a much greater number of combinations of terms of the inferior orders.

This enormous labour, which has occupied M. Delaunay for nearly twenty years, has been performed by him without assistance from any one. Indeed, from the nature of the calculations which are required, it would not have been easy to obtain any effective assistance. In order to insure accuracy, M. Delaunay has omitted no means of verification, and he has performed all the calculations, without exception, at two separate times, with a sufficient interval between them to prevent any special risk of committing the same error twice in succession.

The volumes before us are perfect models of orderly arrangement. Notwithstanding the great length and complication of the calculations, the whole work is so disposed that any part of it may be specially examined with the utmost readiness by any one who may wish to test its accuracy.

Finally, the analytical expressions which have been obtained for the Moon's co-ordinates are converted into numbers, by substituting for the elements the most accurate numerical values which the comparison of theory with observation has made known.

Such is an imperfect sketch of M. Delaunay's labours on the

Theory of the Moon contained in these two magnificent volumes, the former of which appeared in 1860, and the latter in 1867. As I have already stated, they do not include a complete theory of the Moon, but only that which is by far the most difficult and complicated part of that theory, viz., the investigation of the perturbations due to the direct action of the Sun supposing its apparent motion about the Earth to be purely elliptic. Of the investigations which are required to take into account the remaining very small causes of disturbance, and which are intended by M. Delaunay to be included in a supplementary volume, some of the most important have been already completed by him, particularly the calculation of the Secular Variation of the Moon's Mean Motion, and the investigation of the long inequalities due to the action of *Venus*.

I understand also that M. Delaunay is engaged in the construction of new Lunar Tables founded upon his theory.

Your Council, however, has decided that we ought not to await the appearance of M. Delaunay's supplementary researches before we mark emphatically our sense of the value of his labours.

The present work is complete in itself; in it the very difficult and complicated problem of determining the Moon's motion is attacked by a perfectly original method, and that one as powerful and beautiful as it is new. The work has been planned with admirable skill and has been carried out with matchless perseverance. The result is an enduring scientific monument of which our age may well be proud, and which we are happy to distinguish, on this occasion of our fiftieth anniversary, with the highest marks of our approval which it is in our power to bestow.

The Chairman, then delivering the Medal to M. Delaunay, addressed him in the following terms:—

M. Delaunay, il ne me reste plus maintenant qu'à vous présenter cette médaille au nom de la Société Royale Astronomique, qui désire par ce tribut vous exprimer la haute appréciation qu'elle a de vos travaux. Notre Président regrette vivement que l'état de sa santé l'empêche de remplir cette tâche agréable. Il m'a prié de le remplacer dans cette circonstance, et je le fais avec d'autant plus de plaisir que depuis bien long-temps j'ai la plus grande estime pour vos hauts talents, et que j'ai étudié vos belles recherches avec la plus grande admiration, aussi je suis heureux de vous exprimer que notre Société vous a suivi dans votre immense travail avec le plus vif intérêt; et quoique ce travail ne soit pas entièrement terminé, elle sent qu'elle ne peut tarder plus long temps à reconnaître la haute valeur de vos recherches. Nous sommes heureux de vous voir au milieu de nous à cette occasion, et nous faisons des vœux pour que votre santé et vos forces puissent durer de longues années afin d'enrichir la science de plus en plus du fruit de vos grands talents.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :—

President :

WILLIAM LASSELL, Esq. F.R.S.

Vice-Presidents :

G. B. AIRY, M.A. F.R.S., Astronomer Royal.

WARREN DE LA RUE, Ph. D. F.R.S.

Rev. ROBERT MAIN, M.A. F.R.S., Radcliffe Observer.

Admiral R. H. MANNERS.

Treasurer :

SAMUEL CHARLES WHITREAD, Esq., F.R.S.

Secretaries :

WILLIAM HUGGINS, Esq. F.R.S.

EDWARD J. STONE, Esq. M.A. F.R.S.

Foreign Secretary :

Lieut.-Col. ALEXANDER STRANGE, F.R.S

Council :

J. C. ADAMS, M.A. F.R.S., Lowndean Professor of Astronomy, Cambridge.

JOHN BROWNING, Esq.

THOMAS BURR, Esq.

A. CAYLEY, M.A. F.R.S., Sadlerian Professor of Geometry, Cambridge.

JOHN HENRY DALLMEYER, Esq.

E. B. DENISON, Esq. M.A. LL.D.

EDWIN DUNKIN, Esq.

GEORGE KNOTT, Esq.

J. NORMAN LOCKYER, Esq. F.R.S.

Captain WILLIAM NOBLE.

Rev. CHARLES PRITCHARD, M.A. F.R.S., Savilian Professor of Astronomy, Oxford.

BALFOUR STEWART, Esq. M.A. LL.D. F.R.S.

Dome for Sale.

Captain Swann, the present proprietor of Redhill Observatory, wishes to part with the dome, which was put up by Mr. Carrington at an expense of more than 150*l.* He will take 50*l.* for it; it is in as good condition as when first erected. It is of iron throughout, 25 feet diameter.

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